Manufacturing Excellent Engineers

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This thesis is submitted for the degree of Doctor of Philosophy

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Department of Engineering

Declaration

This dissertation is my own work. Aspects undertaken in collaboration with others are specifically indicated in the text.

No part of this dissertation has been submitted for any other qualification.

This dissertation contains a total of 74,504 words, 46 figures and 63 tables and complies with the requirements of the Engineering Degree Committee of the University of Cambridge.

Judith Shawcross

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Abstract

Higher Education Institutions (HEIs) have been criticised by employers, government and graduates themselves, for not adequately developing required work skills.

An example of practice that does develop student skills is a short industrial placement (SIP) where students are expected to solve a real problem in a company, in two weeks, working with one other student. This practice occurs in a one year Masters programme at Cambridge University Engineering Department. This work studies the SIP practice to understand why it is effective and determine lessons that could contribute to solving the wider skills problem.

A five year research timeframe, coupled with an annually run programme, enabled a multi-stage study using an Engaged Scholarship methodology.

The first-stage was an exploratory study that investigated the initial development of SIP skills, using simulated experiences, in a taught HE based module. Skills development was found to be a complex multi-component process. A theoretical skills development framework was constructed from literature and compared with practice. It was determined that five simulated SIP experiences provided the student with sufficient skills to undertake a SIP in practice and, the most significant problem was that SIP skills were not well defined.

The second-stage focussed on defining skills. Skills were found to be context specific and defining skills required both the associated task and its context to be known. With tasks found to be both essential to defining skills and effective in describing what graduates do in practice, a SIP task framework was constructed which was tested on 80 different SIPs in one academic year. The resulting framework comprised twelve problem-solving process-stages, that in total contained 64 different tasks, and five generic task domains.

These generic domains were investigated in the third-stage of this research. These were found to be more extensive and complex than anticipated resulting in a reconfiguration of the SIP framework, the generation of SIP specific domain descriptions and partial completion of task frameworks to describe each domain.

This research has generated a plausible skills development theory for HEIs, and task frameworks to describe a SIP. Further work has been identified to refine the task frameworks and to continue work on the proposed skills development theory.

Publications

Shawcross, J. K. & Ridgman, T. W. 2017. Linking practice and theory using Engaged Scholarship. *European Journal of Engineering Education*. DOI: 10.1080/03043797.2017.1405239 http://www.tandfonline.com/doi/abs/10.1080/03043797.2017.1405239

Shawcross, J. K. & Ridgman, T. W. 2015. Designing Research for Theory and Practice, REES 2015. Dublin.

Shawcross, J. K. & Ridgman, T. W. 2014. Short Industrial Placements - developing an activity based framework to support teaching and learning. *Higher Education, Skills and Work-Based Learning,* 4**,** 3

Shawcross, J. K. & Ridgman, T. W. 2014. Completing the SIP activity framework – what through placement activities should they, and do they, do? *SEFI 2014.* Birmingham, UK.

Shawcross, J. K. & Ridgman, T. W. 2013. Two week, industrial placements for Masters students - What do they, and should they, do? *SEFI 2013.* Leuven, Belgium.

Shawcross, J. K. & Ridgman, T. W. 2012. Manufacturing excellent engineers: skill development in a Masters programme. Engineering Education, 7, 38-50.

Shawcross, J. K. & Ridgman, T. W. 2012. Towards a Skills Development Framework, SRHE Annual Conference.

Shawcross, J. K. Manufacturing Excellent Engineers: Skill Development in a Masters Programme. EE2012, 2012 Coventry.

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I would also like to thank the Engineering Education Research Community in the UK and beyond for their interest and engagement with my work.

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Glossary – Abbreviations in this glossary appear in bold the first time they are used.

Abbreviation		Page no. of definition
CA	Constructive Alignment	43
CSDF	Conceptual Skills Development Framework	61
CSF	Conceptual SIP Framework	116
CUED	Cambridge University Engineering Department	1
EL	Experiential Learning	33
ES	Engaged Scholarship	6
GCF	Graduate Capability Framework	105
HE	Higher Education	1
HEIs	Higher Education Institutions	1
IfM	Institute for Manufacturing	2
ILO	Intended Learning Outcome	44
ISMM	Industrial Systems Manufacture and Management	3
L&ES	Lecture and Exercise Series	22
MC	Manage the client	115
MI	Manage information	116
MP	Manage the project	115
MS	Manage self	115
PMBOK	Project Management Body of Knowledge	143
SE	Self-Efficacy	41
SIP	Short Industrial Placement	1
SDT	Skills Development Theory	56
USEM	Model of Graduate Employability where; **U** = Subject **U**nderstanding, **S** = **S**kilful Practices in context, **E** = Personal Qualities and **M** = **M**etacognition	28
UK-SPEC	The UK Standard for Professional Engineering Competence	2
WWO	Work with others	115

CHAPTER 1: INTRODUCTION AND RESEARCH STRATEGY

There are views expressed by stakeholders such as business, government and students themselves that UK Higher Education Institutions (**HEIs**) are not adequately preparing students for the world of work (CBI, 2015, IET, 2015, Kandiko and Mawer, 2013, Perkins, 2013). This is impacted by many factors including: knowledge and understanding of graduate work, HEI staff with experience of working outside of academia, level of student work experience and connections in a Higher Education (**HE**) programme to real world applications of the curricula. A fundamental aspect of this, recognised by research intensive HEIs delivering Engineering Education (Alpay and Jones, 2012), was developing students' work skills.

Innovations continue to be reported in Engineering Education (IET and EPC, 2017). This recent conference proceedings contains 23 papers that review many practices considered new or innovative in Engineering Education. In general, there are trends towards more skills development, practice, projects and student interaction. However, none of the papers relate to the specific practice of Short Industrial Placements.

One method of developing work skills is a Short Industrial Placement (**SIP**), as named by the author. A SIP combines working on a real industry problem, as a pair, for two weeks, whilst being based at a company. The expected outcome is a clear, evidence-based definition and analysis of the problem and a business case to support the implementation of a solution which is presented to senior company management. This practice was developed by Cambridge University Engineering Department (**CUED**) and has been used for 50 years in their Masters level Manufacturing and Management programmes. However, despite the success of this practice (Ridgman and Wiggins, 2003), SIPs are rarely used in other HE programmes and the theories that underpin the practice have not been systematically identified and reviewed.

A review of literature related to SIPs was undertaken. It was found that:

- SIPs mostly closely resemble consultancy projects used in MBA programmes (Jennings, 2002)
- there was no evidence-based definition or description of what a SIP might involve in terms of skills or tasks
- SIPs are a Work Integrated Learning activity (Cooper et al., 2010) and preparation was essential, both for students and their supervisors

- the development of skills in HE to solve real-world engineering problems was an area that requires further research to identify and validate the most effective methods (Jonassen et al., 2006).

It was concluded that SIPs, and preparing students to undertake them, would be an appropriate area to investigate to gain a better understanding of practice and potentially contribute to the general problem of developing work skills during a HE programme. Such a study is firmly rooted in social science.

1.1 Purpose

The purpose of this doctoral study was to investigate SIPs as a method of developing work skills and specifically contribute by:

- identifying how skills are developed,
- developing a theoretical description of a SIP,
- determining how this knowledge might contribute to developing work skills during HE programmes.

1.2 Background & Context

Whilst there are some in HEI's that would argue that preparing students for the world of work should not be one of their responsibilities (Atkins, 1999) there are many programmes in applied disciplines such as engineering that include a requirement to prepare students for practice. "The fundamental purpose of Engineering Education is to build a knowledge base and attributes….that will develop the competencies required for independent practice" (International Engineering Alliance, 2013). In the UK, the Engineering Council sets the overall requirements for the Accreditation of Higher Education Programmes (Engineering Council, 2014) in engineering, in line with the UK Standard for Professional Engineering Competence (**UK-SPEC**)(Engineering Council, 2016). Since 2006, the Quality Assurance Agency has adopted the Engineering Council's learning outcomes as the subject benchmark statement for engineering.

SIPs are undertaken at the Institute for Manufacturing (**IfM**), part of CUED, as part of an MPhil programme that claims to be able to prepare graduates for work in Industry (Ridgman and Wiggins, 2003). This programme evolved from a training programme which started running over 50 years ago. The original concept was a company neutral, advanced graduate training programme in which students became familiar with a wide range of industrial production techniques and learned to solve real industrial problems in one year (Cambridge University Engineers Association, 1968). A major feature of the programme, then and now, is the SIP in which students solve real problems as opposed to academic problems. Hedlund and Sternberg term these 'practical' problems (Hedlund and Sternberg, 2000) and their key features compared with academic problems are summarised in Table 1.

Characteristics of academic problems	**Characteristics of practical problems**
Formulated by others	Unformulated or in need or reformulation
Well defined	Poorly defined
Complete information	Lacking in information
One right answer	Multiple correct answers
One method of obtaining the right answer	Multiple methods available

Table 1. Key characteristics of academic and practical problems – adapted from (Hedlund and Sternberg, 2000)

In this MPhil programme, Industrial Systems, Manufacture and Management (**ISMM**), the students undertake four SIPs, as a pair. Their first takes place after a four week Induction Module. One module strand was dedicated to developing skills needed to solve practical problems in industry (IfM, 2015). This skills development activity, followed immediately by work in a company, provides an opportunity to study a situation that was a miniature version of the general problem i.e. developing skills in a HE programme and then performing them in a work environment.

1.3 Research Summary and Strategy

A five year research timeframe, coupled with an annually run programme, enabled a multi-stage study. An analysis and evaluation of multi-stage research strategies (detailed later in this chapter) concluded that an Engaged Scholarship research strategy (Van de Ven, 2007) was the most appropriate for this research. As a result, this is not a traditional doctoral study and the thesis is structured to reflect the Engaged Scholarship process and the three rounds of research undertaken. In this section, the research is summarised and the research strategy justified to orientate the reader.

Research Round 1 involved an exploratory study of how skills are developed. A theoretical framework was constructed and then compared with the skills development activities in the Induction Module preparing students to undertake SIPs. This generated a potential skills development theory and found describing skills to be a significant problem for ongoing theory development as well as in practice. Research Round 2 investigated describing skills. It was determined that skills are context specific and to describe skills the associated task and its context needed to be known. With tasks found to be both essential to describing skills and effective in describing what graduates do in practice (Dowling and Hadgraft, 2013) developing a task framework for a SIP was undertaken. A theoretical framework was constructed and then compared with 80 different SIPs in one academic year. This enabled a high-level SIP framework with twelve problem solving process-stages and five through-SIP domains to be identified. The process-stages were further defined at a task level but the through-SIP domains remained uncaptured. This then became the focus of Research Round 3. Three delivery centric through-SIP domains were described by developing theoretical frameworks and comparing them with practice but the two people centric domains skills required a different approach and a full description at the task level requires further work. These through-SIP domains were found to be more extensive than anticipated and resulted in a reconfiguration of the high-level SIP framework and the associated task frameworks require further refinement.

Having summarised the research, an explanation of the research strategy, an overall plan for conducting research (2005), is provided. A determinant of a research strategy (Flick, 2014) is whether research is driven by a question or an object. This study is driven by the need to understand SIP practice i.e. a research 'object'. An 'object' driven approach is considered appropriate to identify a theoretical basis as long as it is sufficiently open to the complexity of the study's focus (Flick, 2014). This involves adopting a strategy of emerging methods (Creswell, 2009) i.e. selecting methods as the study progresses that address the aspects being investigated at that time.

The requirement for an open multi-stage approach led to the adoption of a 'mixed methods' strategy. "Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration." (Johnson et al., 2007). Mixed Methods studies are often multi-stage and enable combinations of quantitative or qualitative methods to be employed as appropriate to the respond to the emerging needs of the enquiry (Creswell, 2009, Creswell and Tashakkori, 2007, Teddlie and Tashakkori, 2010). Such studies are not featured in the Cambridge Handbook of Engineering Education Research (Johri and Olds, 2014) where coverage of multi-stage methodologies is limited to longitudinal studies that involve collecting multiple sets of data from the same students.

The primary philosophy associated with mixed method research is pragmatism (Johnson et al., 2007). This aligns well with the authors pragmatic worldview (Creswell, 2009) and is strongly associated with practice orientated mixed methods research (Creswell and Tashakkori, 2007).

Specific multi-stage, mixed method research strategies were identified as Engaged Scholarship (Van de Ven and Johnson, 2006) and Action Research (Stringer, 2007, Koshy, 2010). An alternative was to view the research as a sequential process with an exploratory study leading to an investigation of a particular aspect. Cresswell (2009) identifies three such strategies – explanatory, exploratory and transformative.

These strategies were evaluated on the following criteria:

- suitable for social science research in an educational context
- suitable for understanding/describing a specific example of complex practice
- be capable of supporting theory generation
- be flexible in terms of method
- with flexibility on stage weighting

The first three criteria were considered essential to achieving the purpose of this research set out in 1.1. The first two checked the suitability to address the problem space and the third provided a way of contributing the wider problem of developing work skills during HE programmes. The last two criteria were considered important to enable the study to respond to the findings at each stage.

Research Strategy	Description	Suitable for an education context	Suitable to investigate an example of complex practice	Capable of supporting theory generation	Flexibility in terms of method	Weighting by stage
Action Research	A systematic and participatory approach that enables evidence-based improvements to practice – considered to be grounded in the qualitative research paradigm	Yes – widely applied in education and teaching	Yes – good for developing understanding	Limited	Yes	No pre-determined predominant stage
Engaged Scholarship	A systematic and participatory approach that works across the theory practice boundary to advance improvements in both	Yes – applied in profession al practice	Yes - good for understanding complex practice	Yes	Yes	No pre-determined predominant stage
Sequential Explanatory	Typically quantitative followed by qualitative research used to explain and interpret quantitative data – particularly useful for explaining unexpected results	Limited	No	Yes	Some	First stage is more heavily weighted
Sequential Exploratory	Typically qualitative followed by quantitative research to assist in the interpretation of qualitative findings to explore a phenomenon and/or develop an instrument	May be – dependent on study	Yes – but potential problems with small sample sizes	Yes	Some	First stage is more heavily weighted
Sequential Transformative	Used for a two stage study with a theoretical lens e.g. gender, race applied over both stages – can be any combination of quantitative and qualitative methods	Yes	May be - unlikely to be the main purpose of such research	Yes	Yes	Weighting adjustable

Table 2: Comparison of multi-stage research strategies

Out of the approaches in Table 2, Engaged Scholarship (**ES**) was selected as it was the only one that met all the evaluation criteria. Confidence in this approach increased on the publication of a successful study (Garner, 2015) that used ES as a mixed method, sequential multi-stage research strategy that enabled emergent research questions to be addressed.

1.4 Engaged Scholarship

ES developed out of concerns about the declining engagement of academia with practice (Boyer, 1996). Boyer used the term ‘scholarship of engagement’ to articulate the engagement movement view in US HE (Kenworthy-U'Ren, 2005), that academia should focus on solving real world problems.

This type of scholarship was seen as being able to bridge theory practice gaps in management science (Van de Ven and Johnson, 2006). It was developed into a research approach and is defined as a “participative form of research for obtaining the different perspectives of key stakeholders in studying complex problems" (Van de Ven, 2007).

Informing both theory and practice is a recognised challenge for those undertaking research in profession related disciplines such as engineering, business and education (Van de Ven, 2007). For academics, their challenges are doing research relevant to practice and creating impact, and for practitioners the challenges are being aware of relevant research and then comparing their practice with theory.

ES is a research strategy that consists of four fundamental research activities (Van de Ven, 2007), problem formulation, theory building, research and problem solving – see Figure 1.

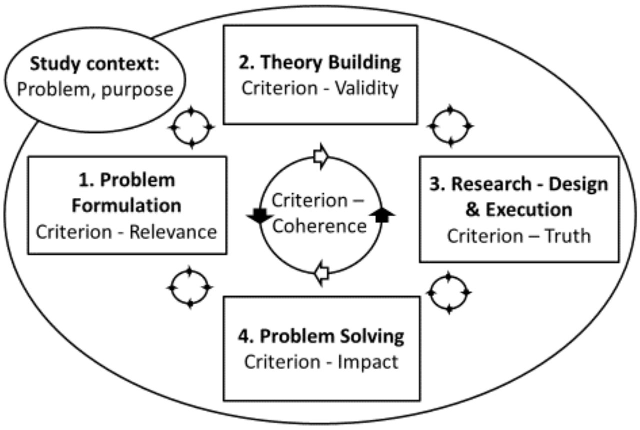


Figure 1. The Engaged Scholarship Approach adapted by Shawcross

The **problem formulation** activity grounds the problem in both practice and the academic literature, to appreciate and situate its multiple dimensions and make sure that the size and scope of the study is achievable with the available resources (Van de Ven, 2007). The outcome is the identification of a research topic and question selected using relevance, size and scope as the most important criteria.

The subsequent research activity, **theory building**, is where a conceptual framework is created, constructed and justified that provides a plausible representation of the problem to be investigated. Here validity is the key criterion.

Research design and execution activities follow where a methodology for testing the conceptual framework is identified, justified and then put into action to generate results where truth is the main criterion.

Problem solving is the final activity where the findings are communicated and then interpreted with the intended audience. This enables conclusions to be drawn and recommendations to be made that can contribute to both theory and practice.

McKelvey, a strong critic of ES from a Management Science perspective, (McKelvey, 2006) notes similarities to Action Research, a methodology used extensively in Education Research (Koshy, 2010) to improve practice. He questions whether the addition of multiple aspects such as research collaborations, big questions and extended time periods will be achievable in real life. For example, company based practitioners and management researchers are likely to have different objectives and company contexts are susceptible to change. Such issues are largely avoided in an EE context, in the authors opinion, as researchers and practitioners are likely to be aligned on their goals and HEI's offer a generally more stable context than companies.

1.4.1 Strengths and challenges

The main strengths and challenges were determined via an analysis of the Academy of Management Review paper (Van de Ven and Johnson, 2006), the first chapter in "Engaged Scholarship in a professional school" (Van de Ven, 2007) and a presentation given at London Business School (Van de Ven, 2010).

<u>Strengths:</u> The four main strengths of ES are summarised in Table 3 overleaf and labelled A, B, C and D, align with the aims and context of this research study.

The author is passionate about making a difference and wants the research to be applied in practice so strength A is important. Strength B aligns with the purpose of this research see section 1.1 and strength C connects with the real world complex problem to be investigated. The research will be inter-disciplinary involving fields including Higher Education, Manufacturing and Management – so strength D is important.

Strength	How they are achieved
A. Increased chance that the research will be applied in practice	A1. By engaging both researchers/scholars and practitioners
	A2. By framing a given problem as an instance of a more general case
B. Increases the likelihood that the research will advance knowledge for theory and practice	B1. Choice of research methods based on the study context and purpose
	B2. Arbitrage – a process of engaging with practitioners and working with different views
	B3 A research process of four interrelated activities - Problem formulation, Theory Building, Research Design and Problem Solving
	B4 Through research collaborations between multiple scholars and practitioners and addressing dual hurdles of quality and relevance
	B5 Triangulation of methods and models increases reliability and validity.
C. Facilitates under-standing of real world complex problems	C1. Use of arbitrage - between researchers and practitioners
	C2. Multiple investigators and perspectives
	C3. Multiple frames of reference
D. Suitable for inter-disciplinary research	D1. Pluralistic process (multi model/theory) & arbitrage

Table 3: Engaged Scholarship Strategy Strengths (summarised from Van de Ven)

<u>Challenges:</u> Four main challenges were identified and labelled: E, F, G and H. They are summarised in Table 4 and evaluated below, to determine if any might cause problems for this research.

Challenge E: The author, although a novice researcher, was equipped to tackle this challenge because they were a mature postgraduate with significant experience in a large industrial company, multiple academic institutions and working in collaborative teams. A key practice stakeholder was the academic who facilitates the skill development activities. This person was also the PhD Supervisor. This relationship did have the potential to cause issues, but they were considered manageable.

Challenge F: The author was based at IfM providing plenty of opportunities to interact formally and informally with most internal stakeholders. This was a part-time doctoral study over five years studying an annual programme, so repeated trials were possible.

Challenge G: Applying ES without prior experience and as a novice researcher was a significant challenge that would require careful reference to the methodology literature.

Challenge H: The authors work experience, practitioner knowledge as a lecturer/trainer and experience of SIPs as a graduate student should enable this to be overcome.

Challenge	The importance of addressing the challenge
E. Creating and managing an effective engagement between researchers and stakeholders	E1. To increase the likelihood that the research will be applied
	E2. To ensure all research stakeholders have clear expectations and are clear about their roles, responsibilities and use of study findings
	E3. To ensure the research team is balanced in terms of skills and background and all research collaborators are motivated and able to work on the project.
	E4. To ensure there is regular communication between collaborators, the collaborators get to know each other and that there are times set aside when the collaborators reflect on how the collaboration is performing.
	E5. To deal with conflicting views and interpersonal tensions arising through use of arbitrage
F. Time Interacting in the study	F1. To increase likelihood of making significant advances in knowledge
	F2. To build relationships and trust
	F3. To be able to observe directly
	F4. Longer study durations can enable deeper learning via repeated trials
G. Applying the ES method to leverage its strengths	G1. Problem Formulation - to ground the research question/problem in observable phenomena, to appreciate and situate its multiple dimensions and to make sure that the size and scope of the study is achievable.
	G2. Theory Building - to develop plausible concepts and models, via triangulation, that represent the main aspects of the observed phenomena and provide a base for new theories to address the research question.
	G3. Research Design - to use appropriate methods to design the research and obtain empirical evidence of the concepts and plausible models for examining the question about the phenomenon to be examined
	G4. Problem Solving - to apply and disseminate the findings from the perspective of different academic and practitioner users – enabling others, not familiar with this type of research, to engage with the work.
H. Being reflexive and objective as a researcher	H1. To achieve internal and external validity
	H2. To ensure research goals are not compromised
	H3. To view the study from both a researcher and practitioner perspective
	H4. To undertake problem driven research

Table 4: Engaged Scholarship Strategy Challenges (Summarised from Van de Ven)

ES, using the model in Figure 1, provides a high-level research design. Having discussed the methodology and method aspects, the underlying philosophical perspectives of ES will be addressed next.

1.4.2 Philosophical aspects of Engaged Scholarship

The philosophical underpinnings of ES are more complex than for most other methodologies. ES adopts a philosophy that includes, and integrates, aspects of what might traditionally be considered alternative philosophies, incorporating key ideas from positivism, relativism, pragmatism and realism (Bechara and Van der Ven, 2007). Ontologically, ES adopts the critical realist position of Bhaskar (Archer et al., 1998) with its mid positioning between positivism and relativism, Rescher's realistic pragmatism (Rescher, 2000) and Campbells relativist evolutionary epistemology (Bechara and Van der Ven, 2007).

The position adopted was summarised (Van de Ven, 2010) as:

- There is a real world out there, but our understanding of it is limited
- All facts, observations and data are theory laden
- Social science has no absolute, universal, error-free truths or laws
- No form of inquiry can be value free and impartial
- Knowing a complex reality demands use of multiple perspectives
- Robust knowledge is invariant (in common) across multiple models
- Models that better fit the problems that they are intended to solve are selected, producing an evolutionary growth of knowledge.

The above statements align with the authors' position and are considered to be internally consistent. This next section evaluates if a research design using ES was appropriate for this study.

1.5 Evaluating a research design

It is necessary to address the quality of a study at a general level (Bernhard and Baillie, 2016). They proposed six tentative criteria at the level of which are presented as the first six in Table 5. A researcher in the process of setting out a research design also has to consider whether it will enable the research problem to be addressed and generate a significant contribution. These further two criteria form part of the list by (Tracy, 2010) and are added to those in Table 5. Against each criteria, an explanation is provided on how each one was addressed in this study.

Criteria	Explanation	How this is addressed
Research question	Worthy topic: relevant, timely, significant, interesting	Development of skills in HE is a nationally and internationally recognised issue and is of particular concern for those providing initial professional education in applied disciplines
Internal consistency of a study	Consistency between research question, methodology, epistemology and ontology	There is a clear fit between the research question and methodology. The methodology is understood in terms of its epistemology and ontology positions and is judged to be internally consistent
Perspective awareness	Awareness of how the researcher views their subject	The researchers' view is understood and articulated. This will enable associated limitations to be considered.
Informed by theory and literature	Significant research cannot be performed without being informed by literature	The study will be informed by literature in relevant fields. The ES methodology requires input from literature at multiple times.
Upholding ethical values	With regard to all stakeholders related to the research	The interests of all stakeholders are respected. It is considered unlikely that any major ethical dilemmas will arise.
Acknowledging different traditions and cultures	Respect and awareness of the perspective of other researchers	The research is carried out understanding that social science research is less familiar in Engineering and will require careful explanation.
Fit for purpose	Design likely to enable the research question to be answered	An ES methodology is likely to be effective in informing both theory and practice - the purpose of this study.
Significant contribution	Design has the potential to generate a significant contribution	An ES methodology is selected as it offers the approach most likely to generate a significant contribution.

Table 5: Criteria to evaluate the quality of an overall study

It is concluded that the research design proposed describes a coherent and appropriate approach that responds to the context and aims of this research study (Shawcross and Ridgman, 2015, Shawcross and Ridgman, 2017).

1.6 Thesis Structure

This thesis differs from a conventional doctoral thesis as three rounds of the ES methodology were applied. It is into divided into 11 Chapters, the first of which is this introductory chapter. Chapters 2 to 4 describe Research Round 1, Chapters 5 and 6 describe Research Round 2 and Chapters 7 to 9 Research Round 3. The final two discuss the findings and present the conclusions.

The three research rounds contain chapters associated with the four research activities of the ES Methodology shown, with colour coding, in Figure 2.

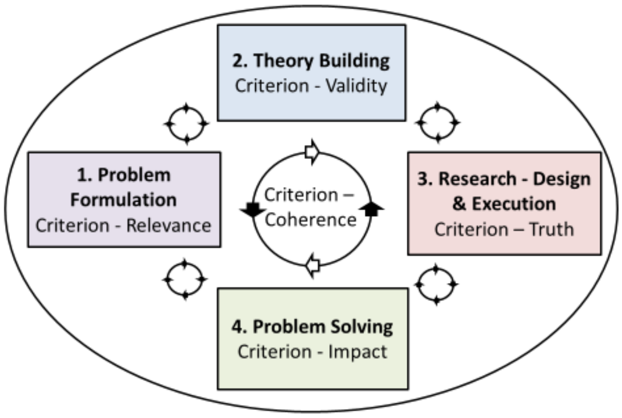
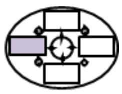


Figure 2. Main activities in ES Methodology showing the colour-coding scheme

Table 6 overleaf, shows the thesis structure, indicating how the chapters relate to the three research rounds and ES research activities. A short description of the chapter content is also provided.

The beginning of each chapter contains a banner based on Table 6 to indicate what is covered in that chapter and how the chapter relates to the work overall. This includes a research activities symbol based on Figure 2 and an extended description of chapter content. An example banner is shown below.

Chapter 2	Research Round 1	Problem Formulation ES Research Activity 	A systematic review of the problem is undertaken in terms of practice and the academic literature is reviewed to diagnose the problem and define the most relevant research question for this research round.

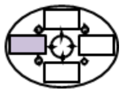
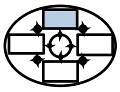
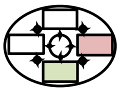
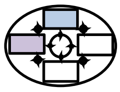
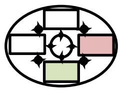
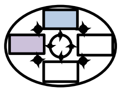
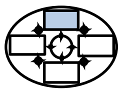
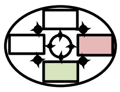
Chapter No.	Research Round	Chapter Title	ES Activity Key	Chapter objective and outline content
1		Introduction and Research Strategy	n/a	Introduce the research related to skills development and set out the research strategy to be used
2		Research Problem Formulation		Define the research question following a review of problem in terms of practice and literature
3	1	Building a Conceptual Skills Development Theory		Build a theory and construct a conceptual skills development framework (CSDF) from literature to answer the research question and test the theory
4		Theory Testing and Evaluation		Test the CSDF on SIP skills development teaching and evaluate the findings. Key finding: SIP skills are not well defined.
5	2	Describing SIP Skills		Define a further research question, justify an approach and build a conceptual SIP framework from literature
6		Testing and Extending the SIP Description		Test the SIP framework, then extend and test the description at a task level. Key finding: Five through-SIP domains require further investigation
7		Describing Through-SIP Domains		Build conceptual task frameworks from literature for the through-SIP domains. Achieved for three out of five domains. Key finding: The two people-centric domains require a different approach.
8	3	Describing people-centric Through-SIP Domains		Build an evidence-based description of the people centric domains using a grounded theory approach. Key finding: Both domains described.
9		Testing and refining delivery centric Through SIP Domains		Test the delivery-centric domains identify tasks and evaluate the findings. Key finding: Tasks identified, but their descriptions require further refining for the SIP context
10		Discussion	n/a	Discussion and evaluation of the research
11		Conclusions	n/a	Distillation of the findings from the research, research contribution and further work.

Table 6: Thesis Structure

CHAPTER 2: RESEARCH PROBLEM FORMULATION

Chapter 2	Research Round 1	Problem Formulation ES Research Activity		A systematic review of the problem is undertaken in terms of practice and the academic literature to diagnose the problem and define the most relevant research question for this study.

The purpose of this research activity was to ground the problem to understand its multiple dimensions, and make sure that the size and scope of the study was achievable with the available resources (Van de Ven, 2007). The outcome was the identification of research questions, from which one was selected, using relevance, size and scope as the selection criteria.

Van de Ven (Van de Ven, 2007) describes four interrelated problem formulation activities: situating, grounding, diagnosing and resolving. These activities often overlap, or happen in parallel, and situating and grounding are multi-component activities. How these different activities were undertaken in this study is shown in Figure 3 with the each “box” being covered in a separate section of this chapter.

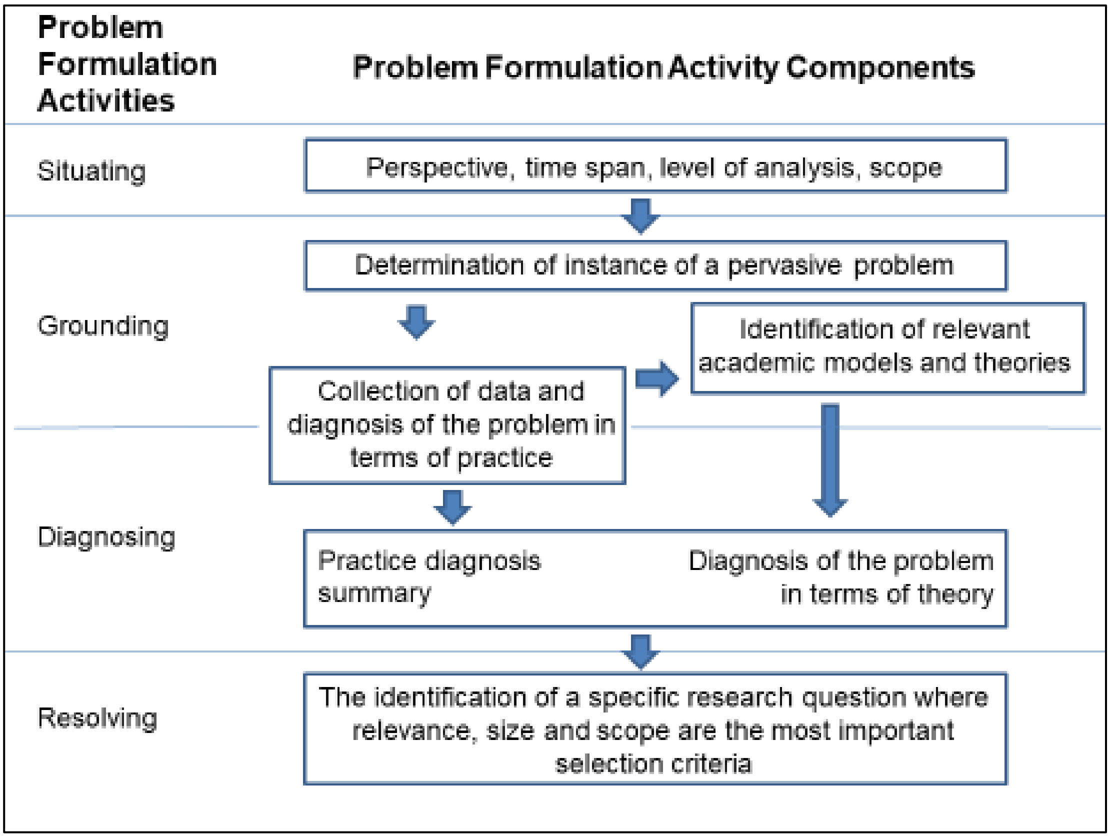


Figure 3: Problem Formulation Activities

2.1 Situating the problem

Situating the problem requires the perspective, time span, scope and level of analysis to be determined.

Research is undertaken in the service of a particular group of stakeholders (Van de Ven, 2007) and determining the foreground perspective from which the problem is addressed is key. In this study, there were three major stakeholder groups:

- students - who would like to have higher levels of work skills as a result of their HE programme (Kandiko and Mawer, 2013, CBI and NUS, 2011),
- employers - who would like to have graduates with higher levels of work skills (CBI, 2015, IET, 2015, CIHE, 2008, RAE, 2007)
- HEI's – whose rating in multiple University Guides e.g. the Guardian (Guardian, 2015) aimed at prospective students, includes the percentage of graduates who find jobs, or undertake further studies, within six months of graduation. It is thus in a HEI's interests to support their students in becoming employable.

This study was undertaken from a HEI and Engineering Degree Programme perspective because the research sponsor was Cambridge University Engineering Department (CUED), who have a strong interest in the continued delivery of excellently rated programmes. Situating the problem, the foreground perspective was that of a HEI with the background perspectives being those related to students and employers.

In terms of scope, a taught Masters programme delivered in one academic year was selected primarily because the practice example to be examined was part of a full time, 9 month taught postgraduate Masters programme. More specifically, the scope was the Industrial Systems, Manufacturing and Management (ISMM) MPhil programme, taught by the Institute for Manufacturing (IfM), one Division of CUED and the level of analysis was the individual student. The overall timespan for the study was five years and the annual cycle of the programme provides multiple opportunities for research.

A further description and analysis of the ISMM programme follows to narrow the scope identifying the specific and relevant aspects to be studied.

2.1.1 Historical background

The initial programme, which started in 1966, was a response to employers who had commented that Cambridge engineering graduates were 'too academic' and not ready to solve real problems in practice (Cambridge University Engineers Association, 1968). A non-accredited post-graduate training programme, was designed to prepare graduates to solve real industry practice problems using SIPs. This was designed to be taken by graduates shortly after the completion of their undergraduate studies and attracted a cohort of students predominantly from the UK (Fell, 2015)

By the early 2000’s, this programme was struggling to attract students so it was converted into an accredited MPhil programme, ISMM. In this programme the number of SIPs was reduced to four, the taught component was increased and a research dissertation was included. ISMM now attracts at least four applicants for every place and a typical cohort of around forty students contains around 20 nationalities, 50% EU and 50% rest of word, with most students having the equivalent of a 1st class degree in Engineering or another numerate discipline. This has brought additional challenges of working with students from different cultures, many having English as a second language and a broader ability range due to variable degree classification standards.

Each programme is named by the year since the start of the programme. The 2011/2012 course is Course 46 or C46.

2.1.2 ISMM programme structure

ISMM has a Programme Specification with two associated JACS (Joint Academic Classification System) codes, H700 for Production and Manufacturing and N200 for Management, and is aligned with the Quality Assurance Agency (QAA) Engineering Subject Benchmark Statement (QAA, 2015).

The structure of ISMM has remained largely unchanged since its launch in 2004. About 23 weeks of this 36 week programme (not including holidays) are dedicated to the preparation of graduates for practice roles in industry and the remaining time is spent on a research dissertation. Table 7 overleaf provides a breakdown of the course components.

Course Components	Weeks	Description
Induction Module Part 1	4	Taught module including lectures, industrial visits and SIP skill development activities
SIP1 - Induction	2	Students based in industry solving problems focused on Induction Module content
Induction Module Part 2	1	One week taught module focusing on key aspects of IfM Research e.g. service, sustainability
Industrial Systems Module	2	Taught module including exercises to simulate practice and one exercise undertaken in a factory.
SIP 2 – Industrial Systems	2	Students based in industry solving problems focused on Industrial Systems Module content
Entrepreneurship	1	Taught module with a group practice project
Marketing & Strategy	1	Taught module with many components including design.
SIP 3 – Marketing	2	Students based in industry solving problems focused on the Marketing & Strategy Module content
Technology and Innovation Management(TIM)	1	Taught module with cases and exercises to apply frameworks and tools.
Manufacturing Processes (MP)	2	Taught module with multiple industrial visits and a significant module project
SIP 4 – TIM or MP	2	Students based in industry solving problems
Individual Research Project	13	Students select a topic of interest, undertake a piece of research and submit a Dissertation
Leadership and Management	1	3 days undertaking Leadership exercises & 1 day taught
International Study Tour	2	Tour of a particular region or country to appreciate the industrial innovation context and investigate industrial management practice and manufacturing processes

Table 7: Outline of ISMM programme for C46 - 2011/12

One of the two stated aims of the ISMM programme was to provide course members with the skills and knowledge to be immediately effective in their industrial careers. In terms of programme learning outcomes, two categories are directly related to SIPs, Practical skills and Transferable skills.

C. Practical skills – able to:

1. Undertake problem identification and definition

2. Research appropriate background information and theories

3. Determine the appropriate methodology for problem solution

4. Identify, gather, analyse and evaluate appropriate data

5. Prepare a business and finance case to justify a recommendation

D. Transferable skills – able to:

1. Communicate effectively (in writing, verbally and graphically)

2. Presentations

3. Written reports

4. Project management

5. Working with others

6. Networking

IfM academic staff lead the taught modules and skills development activities. They are supported by a number of industrial practice tutors in sourcing and delivering SIPs. The researcher has been involved with ISMM for three years prior to this study leading the Technology and Innovation Management Module and as a SIP practice tutor.

The preparation of students for industrial roles comprises three main strands, woven through the programme:

- SIPs - teaching SIP skills during the Induction Module, followed by four different SIPs at intervals throughout the programme
- taught modules to cover relevant knowledge, theory and tools
- industrial visits, typically 30 to 40 in one programme, to develop understanding of the context and practice of industrial and manufacturing management.

Of these strands, SIPs was the most directly relevant to developing SIP skills (although the other two may contribute) so teaching SIP skills in Induction was the initial research focus. In terms of levels of analysis, the individual level was considered the most relevant, as each individual student needs to acquire skills.

2.1.3 Summary - situating the problem

A HEI teaching perspective was taken, focussing on the practice of teaching SIP skills in the 4 week duration ISMM Induction module of C46. This practice was selected for investigation as it most closely parallels the general HE situation i.e. preparing HE students to be able to work in practice. This research task was of an appropriate size for research round 1.

2.2 Grounding the problem

Grounding a problem requires an exploratory study into the nature, context and knowledge about the problem domain (Van de Ven, 2007). The study can involve a range of activities including direct observation, talking to casually people about the problem, reviewing literature and personal experience.

Three key aspects are:

1. establishing that the problem was an instance of a pervasive problem - this increases the chances that the findings will contribute to theory
2. the collection of data to diagnose the problem in terms of practice
3. the identification of relevant academic models and theories to diagnose the problem in terms of theory.

Aspect 1 is discussed below, aspect 2 is covered in section 2.3 and aspect 3 in section 2.4 as set out in Figure 3 at the beginning of this chapter.

2.2.1 Pervasive Problem

In Chapter 1, the case was made that developing work skills in graduates was a pervasive problem as seen by employers, governments and students. However, the case was not made from the teacher perspective, so views were sought from HE teachers involved in teaching skills from applied disciplines of Engineering, Business, Entrepreneurship and Medicine, via informal discussions.

These discussions confirmed that the development of work skills during HE programmes was a significant challenge and three general observations emerged:

- being able to simulate a real work task was important and motivates the students to learn
- designing, developing, facilitating and managing the required teaching resources for skill development activities was time consuming
- assessing skills was difficult and takes time as each student must be observed performing the skills.

These observations align with the prior experience of the author and establish skill development as a pervasive problem where limited time to carry out teaching related tasks was a major issue.

2.3 Grounding and diagnosing the problem – practice perspective

This section describes the SIP skills development practice in the ISMM Induction Module and incorporates appropriate diagnosis to enable a deeper grounding of the problem. Due to timing, the Induction Module skill development activities could not be observed. This was substituted by reviewing course documentation and interviewing course teachers.

The Induction Module was the first module of ISMM, it lasted four weeks and included a range of lectures, activities and factory visits designed to introduce the students to key aspects of manufacturing industry and its management. To ensure the SIP skills development activities were identified, questions were asked of the academic responsible for leading the skills development activities and the course tutor responsible for the Module.

The majority of the Induction Module activities had been classified to point students to six different module strands. This classification was completed and refined with the academic to ensure that the SIP skills development activities were identified. The six strands and their time distribution in C46 is presented in Figure 4.

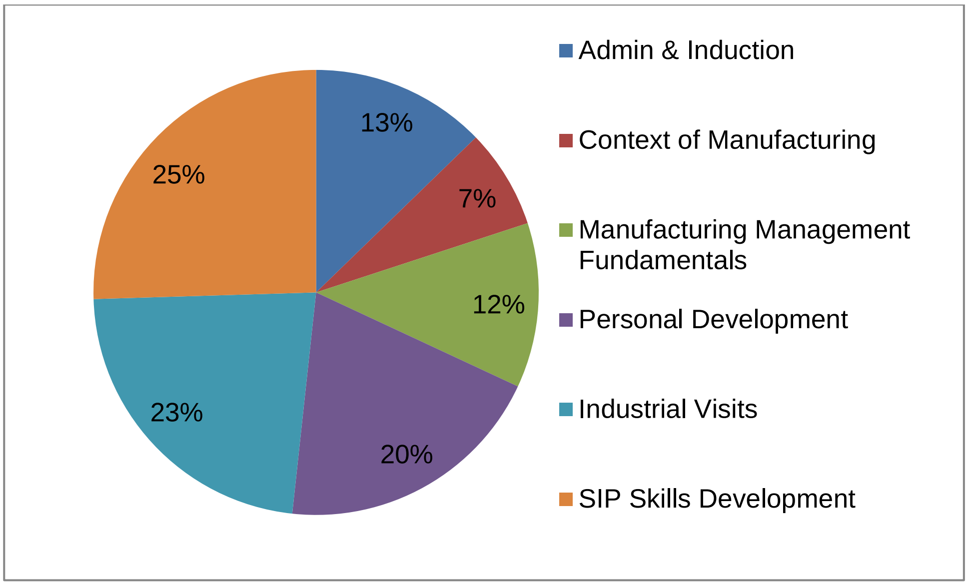


Figure 4. C46 Induction Module – Time distribution by module strand

The SIP Skills Development and Personal Development strands account for 45% of the module and directly relate to preparing a student for SIPs. The SIP Skills Development strand focuses on the skills required to solve real problems in an industrial context, in a small team and within a limited time. The Personal Development strand focuses on general skills e.g. report writing and effective speaking. The SIP Skills Development strand was selected as the research focus as this prepared students for practice and students were considered less likely to have skills in this area.

Within this strand, there was contact time for solving simulated SIP problems (21%) and to teach specific parts of the SIP process e.g. data gathering (4%). Solving simulated SIP problems was selected for study as these teaching activities are fully focussed on skills development. They include an interactive lecture followed by five exercises that simulate a real practice problem. From now, this '**L**ecture and **E**xercise **S**eries' will be referred to as the **L&ES**.

2.3.1 Teaching activities to develop SIP skills.

The interactive lecture provided an explanation of SIPs, an overview of the recommended problem solving process and an introduction to some tools and techniques.

The first four exercises were class-room based simulations featuring typical SIP problems in two fictitious companies. Students are divided into teams and provided with an information pack. The information was deliberately incomplete and contained conflicting viewpoints to simulate a real workplace situation. All teams worked on the same problem concurrently.

During the exercises the academic carefully monitored progress, regularly visiting each team to observe their actions and ask questions to understand their approach. He ensured that at least one team achieved a workable solution as this demonstrated to the class that the task was possible in the time available and encouraged others to achieve this. At the end of each exercise, each team presented to the whole class. Students got immediate feedback on their solution, problem solving approach and presentation and they also learnt by observing how other groups approached the given problem. There was a model answer for each exercise, which was used to emphasise key learning points.

The fifth exercise, attempted to simulate a SIP more closely. Students were required to work in an unfamiliar environment, at a different location, for one day where they undertook practical work. They gave a presentation on a subsequent day and wrote a report. Students were given feedback on both, to help them improve their skills and understand expected standards.

The five exercises are summarised in Table 8. Further details of Exercise 1 can be found in Appendix 4. A4.2 contains the Briefing Note and A4.3 the Model Answer.

Exercise	Description
Exercise 1 Timetabled time = 7.25 hours	Students, in groups of two or three, determine a feasible solution to improve order processing operations. This involves: 4.75 hours – Complete the activity after a short briefing. This activity starts during an afternoon and finishes the following morning to enable students to extend their working time. 1.5 hours – Immediately following the end of the problem solving activity there is a presentation session (the class is split between 2 tutors) – Each team presents their solution, tutors provide verbal feedback and students are given some time to reflect. 0.5 hours – A model solution is presented later that day.
Exercise 2 "Believe It" Timetabled time = 9 hours	**"Believe It!"** is a SIP simulation designed to give students experience and confidence in resolving "messy" manufacturing situations by applying structured analysis. It is based upon actual situations in a margarine factory. There are three interrelated but independent exercises 2a, 2b and 2c which students tackle in the same group of about 6 members. Each exercise takes 3 hours. Following the problem solving activity, groups are required to present their analysis and solution. Feedback is given and a model answer is available.
Exercise 2a	This exercise involves the construction and application of process flow charts to conduct margarine production bottleneck analysis.
Exercise 2b	This exercise involves undertaking a strategic evaluation of alternative location proposals for margarine packing facilities.
Exercise 2c	This exercise involves the development of a new layout, subject to constraints, for the palletisation and warehousing process.
Exercise 3 Timetabled time = 10.25 hours	Students work in groups of two or three and are given one of a range of practical assembly process improvement problems related to a multi-component assembly. The projects take place in the main Engineering Department Workshop situated about 1.5 miles from IfM so they have to plan ahead, dress suitably and work out how to travel there. Many projects involve designing and producing a jig.

Table 8: SIP skill development exercises

The academic who leads the SIP skill development activities believed that the exercises along with the feedback adequately prepared students to undertake SIPs as he observed a general improvement in student performance throughout the exercises. There was no formal assessment of skills during the L&ES, this happens both during and after a SIP and is reviewed next.

2.3.2 Teaching and assessment during SIPs

Directly following the Induction Module, students undertake their first SIP in teams of two, supported by a tutor. Tutors have an initial understanding of the SIP problems, as they agreed briefs with each company. Briefs are typically one page of A4, comprising a short company introduction, a description of the problem and some indicative deliverables. Most tutors meet their SIP groups before they start to make sure the brief was understood. The tutor gains an understanding of student progress when they meet the students on the first Friday at the company. Tutors also visit the company on the second Friday to assess the presentation and the company reaction to their work. The students complete a report, for submission on the following Tuesday, which their Tutor marks.

2.3.3 Assessing SIPs

The SIP marking scheme contained ten assessment categories. These categories were analysed by the author, using the marking sheet descriptors, to identify the activity being assessed. A summary of the results is shown in Table 9.

The combination of problem solving and project management activities correlated most closely to the SIP skills being taught in the L&ES. As seen in Table 9 these account for 41% of the assessment.

SIP Assessment Category	Marks	Activity Assessed	% Overall
Interim Tutorial	10	Meeting Management	8%
Professional Approach	10	Personal Management	8%
Presentation Structure and Content	20	Making a Presentation	25%
Presentation Delivery and Style	10		
Quality of Approach	15	Problem Solving	33%
Report Content	10		
Meeting Project Objectives	15		
Task Management	10	Project Management	8%
Structure and Style of report	10	Report Writing	17%
Standard of English	10		
Total	120		100%

Table 9: SIP Marking Scheme

Assessment data from the first SIP of C45 was analysed, see Table 10 below.

	Cohort 45 SIP 1	
	Overall Mark (%)	SIP Skills Mark (%)
Mean	73	76
Range	64 - 82	64 – 87

Table 10. Assessment Data form SIP 1 in C45

The assessment scheme was designed to work at the team rather than the individual level and most assessment categories, including SIP skills, were assessed on a team basis. For C45, all students appeared to pass both the overall and the SIP skills aspects (the pass mark was 60%) however these may not have been achieved at an individual level. Further evaluation of the SIP marking scheme was limited because there was no formal definition of SIP skills.

2.3.4 Definition of SIP skills.

A description of SIP skills was collated using: the practical and transferable skills definitions in ISMM Programme Specification (see section 2.1.2), lecture slides describing SIPs to the students (Ridgman, 2011), facilitator guides associated with the SIP preparation activities (Wiggins, 2002, Ridgman) and discussions with the academic. See Table 11.

	Skills in Programme Spec	**Further aspects identified**
1	Undertake problem identification and definition	Setting problem boundaries
		Defining problem levels – strategic and tactical
2	Research appropriate background information and theories	Ability to sift information to determine relevant aspects
3	Determine appropriate methodology for problem solution	Apply a general problem solving process
		Apply a data driven, logical approach
		Select appropriate tools and techniques
4	Identify, gather, analyse and evaluate appropriate data	Ability to use available data, recognising common data problems e.g. opinion passing as fact, missing data, inaccurate data
5	Prepare a business and finance case to justify a recommendation	
6	Communicate effectively (in writing, verbally and graphically)	Making presentations. Writing reports.
		Communicating regularly as a team to share progress and test ideas
7	Presentations	Considered a subset of 6 above
8	Written reports	Considered a subset of 6 above
9	Project management	Ability to generate a written plan including tasks and milestones. Reviewing plans to assess progress. Identifying which tasks should be done as groups or as individuals.
10	Working with others	See aspects of 6 and 9
11	Networking	

Table 11: Collating a practice definition of SIP Skills

An analysis of Table 11, as negotiated with the academic, identified four distinctive but overlapping skill sets that are being taught in the SIP preparation activities:

- solving industrial problems; skill references 1 to 5
- working with others (in the context of solving industrial problems in limited periods of time); skill references 10, 6 and 9
- managing a project (in the context of a SIP) ; skills reference 9
- making presentations (related to a SIP); skill references 6 & 7 also overlaps with solving industrial problem skills as the presentation content will reflect these skills.

Thus, a practice definition of SIP skills was identified.

2.3.5 Summary – practice perspective

Grounding and diagnosing the problem in terms of practice has identified:

- a specific set of exercises that simulate solving real problems in industry, within a limited time, whilst working as a team
- formative assessment was undertaken by tutors throughout the L&ES and they are confident that student skills improve
- the summative SIP marking scheme was designed to work at the team level and does not provide sufficient evidence to assess an individuals' SIP skills
- SIP skills are not clearly defined so a practice definition was collated comprising four elements: solving industrial problems, working with others, managing a project and making presentations

The practice diagnosis was that the L&ES was perceived to be effective at developing SIP skills. However, summative assessment mechanisms are problematic and a significant contributing factor was that SIP skills were not sufficiently defined.

2.4 Grounding the problem - academic view

The objective of grounding and diagnosing the problem in the academic literature was to identify and then apply models or theories to ascertain the specific nature of the problem in context. In the previous section, the problem area was narrowed to the teaching activities associated with developing SIP skills, identified as solving industrial problems, working as a team, planning a project and making presentations.

This section investigates the definition of a skill before identifying three fields of academic literature related to skills development to be reviewed. Each of these fields are reviewed in turn to identify the models and theories relevant to this study.

2.4.1 Defining skill

There are a number of definitions of skill relevant to this skill development context (Moon, 2004, Tight, 1996, Eraut, 1994, OUP, 2014). Amongst these there was a high level consensus that a skill is ‘the ability to do something’. However most definitions also include a qualifying statement on how a skill is acquired or performed. This was where the variation in definitions occurs and where subjective elements were introduced diluting the clarity of the definition.

Knight and Yorke preferred the term ‘skilled practice’ over ‘skill’ to reflect that skills are context-specific and not easily transferable (Knight and Yorke, 2004). This is demonstrated by an example of ‘making tea’. If ‘making tea’ is undertaken in a kitchen there will be different skills required than if ‘making tea’ happens in the wild. So skills can only be specified when the context is known, and transferability is likely to depend on the degree of similarity between contexts.

Skills also vary with the complexity of ‘the activity’ to be done and many can be broken down into multiple layers of supporting skills – which in themselves will also be context-dependent. Continuing the earlier example, ‘making tea’ in the wild would require supporting skills of ‘building a fire’ and ‘lighting a fire’ which would again vary with context such as type and dampness of wood.

It can be seen from the above that it is both an activity and its context that determines the skills required. So, to define skills one must know both the activity and the context. Some studies that avoid the context issue (CIHE, 2008, CBI, 2011) and describe ‘graduate skills’ at a high level such as ‘communication’. Such definitions are at too high a level to be interpreted consistently by different communities.

2.4.2 Academic fields associated with Skill Development

Skill development is a somewhat dispersed field of knowledge that resides in topics associated with a particular skill as well as broader academic fields.

Three broad academic fields associated with developing SIP skills in HE are identified:

- **Professional Expertise** - solving real and unstructured problems was considered to be the “essence” of professional expertise (Eraut, 1994) and planning projects and team work were key features of an industrial professional’s work.
- **Graduate Employability** - enabling graduates to develop employability skills e.g. team working and communication, demanded by Industry (IET, 2015)
- **Higher Education (HE) Teaching and Learning** - because this was an investigation of the teaching of skills during a Masters-level programme.

The lack of prominence of **Professional Expertise** as an academic field lies in ancient roots, where rationality and intellect were considered superior to practice and experience (a proxy for expertise) (Dewey, 1916). In the 1930’s there was a renewed interest in preparing people for practice e.g. the establishment of the Academy of Management in 1936 (Academy of Management, 2015) to develop an understanding of the practice of management using scholarly research. Of the work in the latter half of the 20th century it was work by Schön (Schön, 1987) and Eraut (Eraut, 1994) that has been most cited related to the general development of professional expertise.

Whilst this field has a long history, it was not until 2006 that a handbook “Development of Professional Expertise” was published (Ericsson et al., 2006). Expertise is defined in its introductory chapter as “the characteristics, skills and knowledge that distinguish experts from novices and less experienced people”.

The academic field of **Graduate Employability** in the UK grew significantly from the late 1990’s. A number of drivers contributed including the growing numbers of students in HE (Bolton, 2012), the Dearing Report (Dearing, 1997) and the inclusion of ‘Employability’ as a measure of HEI performance (HEFCE, 2001). HEFCE and the Higher Education Academy collaborated to provide a point of reference on employability for HEI’s. The resulting **USEM** model of Graduate Employability (Knight and Yorke, 2002) established a multi-dimension evidence based view defining graduate employability as the “the possession of the understandings, skills and personal attributes necessary to perform adequately in a graduate-level job”.

The third academic field was **HE Teaching and Learning.** HE in the UK, was defined for this study, as education delivered by degree awarding bodies (typically universities) (QAA, 2014). All HE programmes should publish programme learning outcome statements (QAA, 2006). Teaching should be designed and delivered to enable all students to achieve the stated outcomes. Although the primary focus of this research was teaching, this was only considered successful if the students achieved the intended learning outcomes i.e. they learn. So teaching and learning have to be considered together.

Although there are earlier studies, research related to HE Teaching and Learning grew following the publication of 'What's the use of Lectures' in 1972 (Bligh, 1998) and the field has continued to grow since. Teaching was defined as 'the work of a teacher' (OUP, 2014) and learning as 'the acquisition of knowledge or skills through study, experience, or being taught' (OUP, 2014).

HE Teaching and Learning in this study covers the taught programme aspects and not any co-curricular or extra-curricular activities that students might engage in. In HE, a course curriculum is defined (QAA, 2006) using four categories of programme learning outcomes: knowledge and understanding, intellectual skills, practical skills and transferable skills, emphasising the need to teach both knowledge and skills.

The key bodies of knowledge and how they interrelate is shown in Figure 5 below.

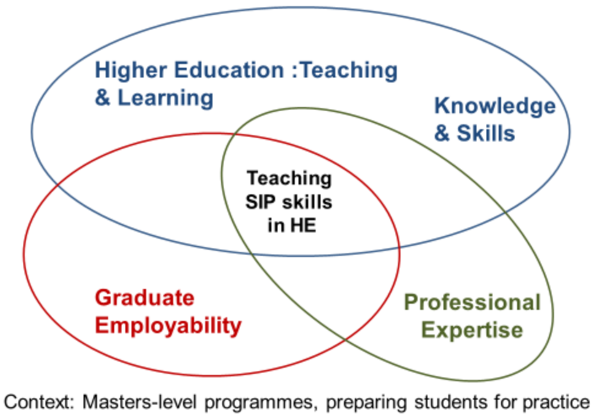


Figure 5. Academic bodies of knowledge related to the teaching of SIP skills

Aspects of professional expertise can be learnt inside and outside of a HE programme. Some programmes include team-working, working on real problems and presentation skills however working in a business environment with a range of different people can only be learnt in practice. This positions the field of professional expertise as overlapping that of HE programmes.

Graduate employability as a whole overlaps with both HE Programmes and Professional Expertise but also retains a distinct non-overlapping area where generic aspects are developed. At a more detailed level the USEM Model of Graduate

Employability has four areas; Subject **U**nderstanding, **S**kilful Practices in context, Personal Qualities (**E**) and **M**etacognition (Knight and Yorke, 2002).

- Subject **U**nderstanding (**U**) overlaps with the propositional knowledge content of HE programmes and overlaps with Professional Expertise for graduates who work in professional roles related to their HE programme.
- **S**kilful practices (**S**) overlaps with the learnt procedural knowledge in a HE programme and with learnt practices outside of a HE programme such as those gained through work experience on a summer internship.
- Personal Qualities (**E**) and Metacognition (**M**) may be developed as part of a HE programme but are rarely a formally defined component of a programme (Knight and Yorke, 2002). E and M are also recognised aspects of Professional Expertise so the overlap with this field was also applicable

Teaching SIP skills in HE was positioned where all three fields overlap.

In the following sections, reviews of each of the three academic fields are conducted to identify and critically evaluate relevant theories and models related to SIP skills and how they are developed. Following the literature review the problem will be diagnosed from an academic perspective. Finally, the specific research problem and question for this study will be resolved.

2.4.3 Professional Expertise

In this section, complex problem solving is located within the field of professional expertise and compared to professional engineering registration requirements. Different facets of expertise are investigated before reviewing relevant theories and models of learning in the workplace. The key points relating to how SIP skills can be taught are then summarised.

Workplace engineering problems are typically ill-structured and complex, offer multiple solution methods, have non-engineering success standards and constraints as well as challenges with unanticipated problems and distributed information (Jonassen et al., 2006).

Whilst 168 strategies for solving problems have been identified (Woods, 2000), only 10 of these related to solving complex problems. Eraut (1994) maintains that in complex situations it is virtually impossible to establish a clear rationale for a proposed solution without using a deliberative process requiring deliberative expertise.

Eraut defined deliberative expertise (Eraut, 1994) as the ability to;

- define an approach to the problem to be able to carry out a project both effectively and efficiently
- solve difficult, ill-defined problems - where analysis, consultation, deliberation and judgement are considered crucial aspects.
- think strategically i.e. an ability to conceptualise and take multiple different perspectives.
- work in a team and undertake consultation.

Deliberative expertise appears to be a good match with SIP skills. The first aspect links to a general aspect of professional work, delivering an agreed outcome in a specified time, whilst coping with multiple competing demands and changing situations (Eraut, 1994, Schön, 1987). The second and third aspects are probably the most ‘deliberative’ aspects of the expertise with the final aspect recognising the social context of the work.

It is interesting to note that Eraut describes deliberative expertise as a set of activities that includes defining an approach to the problem and thinking strategically. This combination located within deliberative expertise positions this expertise as a non-context specific skill i.e. a high-level general skill that would be valuable for any graduate destined for professional roles to learn.

An engineering degree is not intended to produce fully fledged professionals, as graduates require further training and experience over several years before attaining professional status (Hanrahan, 2014). But, experience of the context of engineering applications and solving real-world problems in the face of constraints, risks and uncertainties is essential to developing a graduates’ ability to exercise judgement as well as act appropriately and competently in real-world situations. The UK Standard for Professional Engineering Competence (UK-SPEC) (Engineering Council, 2016), which describes the competence requirements that have to be met for professional registration, is aligned with the activities involved in deliberative processes. However, these activities are distributed throughout different sections of UK-SPEC and would not necessarily have to be demonstrated within the same project. This suggests that newly accredited Professional Engineers may not have demonstrated a competence in deliberative expertise.

There are opportunities to develop complex problem solving and professional skills within Engineering Degrees through team based capstone or design projects (Litzinger et al., 2011), but these are most often done in an academic context. In a review of the development of expertise in relation to Engineering Education (Litzinger et al., 2011) it was concluded that engineering education should encompass a set of authentic learning experiences to enable students to develop and apply skills fluently. Whilst this conclusion would appear sensible, the paper only considers the development of expertise from a narrow range of sources, presents attributes of experts and describes how they might be developed rather than expertise itself, and lacks a clear definition of how expertise is related to skills.

Combining periods of professional practice experience and Higher Education in a concurrent system (Eraut, 1994) offers greater opportunities to develop expertise. Work Integrated Learning (Cooper et al., 2010) is the term used to describe work experiences that are incorporated as an intentional aspect of a programme where learning is situated within the act of learning. There are multiple ways this can be achieved including field work, placements and internships. Using SIPs within a Masters level programme is an example of Work Integrated Learning.

The curriculum for a profession/applied discipline programme should be aligned to its aims which may be contextual - more orientated to producing professionals able to perform in the workplace - or conceptual aimed at producing graduates with a firm disciplinary grounding (Muller, 2009). ISMM is a clear example of a contextual programme. In such contextual programmes it is important to teach process knowledge and in ways that enable propositional knowledge to be applied in practice as Eraut maintains that professional work of any complexity requires the use of several different kinds of knowledge in an integrated, purposeful manner (Eraut, 1994).

Expertise is also expected to develop via experience. The ‘Reflective Practitioner’ (Schön, 1983) and the ‘Stages of skill acquisition’ model (Dreyfus and Dreyfus, 1986) are general models of developing expertise through experience. Eraut (Eraut, 1994) is critical of both models considering that the Dreyfus’s model largely neglects deliberative work, providing an analysis of skilled behaviour where both rapid situational interpretation and decision making are required, while Schön’s Reflective Practitioner model is better considered to be a theory of metacognition. Winch considers these to be anti-intellectualist accounts of expertise (Winch, 2010) that question the importance of theoretical knowledge and portray expertise as developed through long periods of practice in a domain. Collins (Collins, 2013) holds that they stress only one facet of expertise i.e. the degree to which performance changes as a novice develops through experience to become an expert. He suggests two further dimensions: the requirement for tacit knowledge and the degree to which an expertise is rare. Kotzee (Kotzee, 2014) argues that social skills or understanding should replace the novice to expert journey as a third factor in differentiating forms of expertise.

Expertise is now established in the literature as being multi-faceted construct with knowledge recognised as an important component. In studies of clinical decision making expertise reviewed by Eraut (Eraut, 1994), where propositional knowledge is particularly important, it was found that the difference between a novice and an expert was not how much they knew, but how they had mapped their knowledge and how readily this could be accessed in practice. In relation to deliberative processes, Eraut (Eraut, 1994) identified three types of important knowledge: procedural, propositional and situational. Young and Muller capture the current state of the field stating that "all professionals have an obvious need of both theoretical knowledge and practical expertise, but distinguishing between the different kinds and how these relate to expertise remains to be fully resolved" (Young and Muller, 2014).

Relevant work experience was widely accepted as important in developing professional expertise. So theories and models of how individuals learn from work are reviewed below, considering those classified by Dochy (Dochy, 2011) as well as Action Learning (Revans, 2011). These fall into two broad categories – those concerned with aspects of the learning process and those that relate to the nature of the experiences involved.

In terms of the learning process, it was Kolb (Kolb, 1984), drawing primarily on the work of John Dewey, Kurt Lewin and Jean Piaget, who proposed an Experiential Learning (**EL**) Theory which offered an approach to education and lifelong learning that strengthened the critical linkages among education, work and personal development. The theory was intended as a model of the dimensions underpinning experiential learning and is shown in Figure 6 overleaf.

This model identifies a four stage activity cycle connected by two cognitive processes and indicates how they relate to knowledge forms. Kolb presents this as a general model of learning through experience and not specifically for the development of skills.

The key features are a concrete experience, followed by an opportunity for reflection to consider the relationship between experience and abstract concepts, and active experimentation to extend or test knowledge in a different situation. It also captures the dialectic process of learning highlighted by Lewin (Kolb, 1984) that learning was best facilitated where there was dialectic tension and conflict between a concrete experience and abstract concepts.

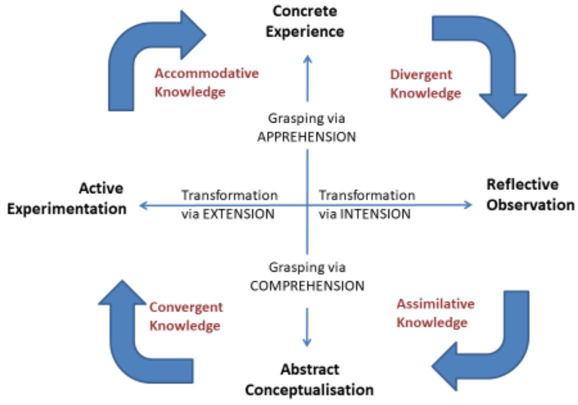


Figure 6. Structural dimensions underlying the process of experiential learning redrawn version of Figure 3.1 (Kolb, 1984).

EL overlaps with Mezirow's theory of Transformational Learning, which is concerned with how adults make sense of experiences. Transformational Learning involves learning from a disorientating experience by critical self-reflection, which leads to the reformulation of meaning, giving a better understanding of that experience. This could be seen as overlapping directly with Reflective Observation and Abstract Conceptualisation following an experience. Schön's (Schön, 1987) contribution was highlighting the importance of reflection in developing professional expertise and overlaps with the upper part of Kolb's model.

Whilst all dimensions are likely to contribute to learning, the circular model was perceived as being too simplistic (Race, 2010, Coffield et al., 2004). In practice, there was likely to be more interaction and some aspects can happen concurrently rather than sequentially. However, the circle does connect to the theory that a number of related experiences are required to support a person's learning. This was a key feature of Dewey's Model of Experiential Learning shown in Figure 7 (Kolb, 1984, Dewey, 1938) which Kolb excludes from his model. Another feature of Dewey's model is purpose or motivation which could be argued as a dimension absent in EL.

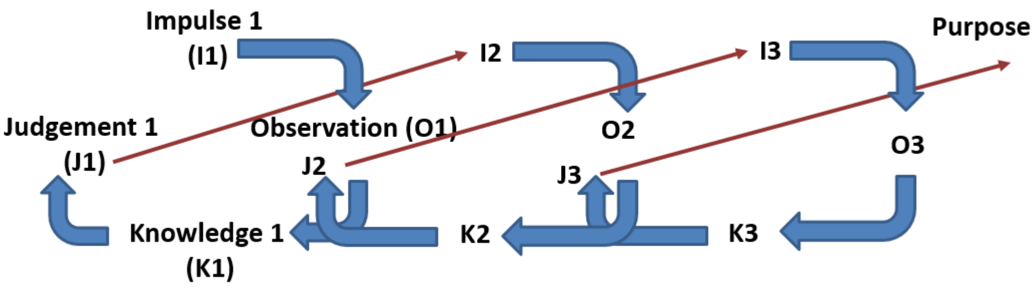


Figure 7. Dewey's Model of Experiential Learning - redrawn (Kolb, 1984)

The theory of situated learning (Lave and Wenger, 1991) states that learning is embedded in the activity, culture and context and is social by nature. In terms of learning from experience, it is thus important to construct learning experiences that are situated appropriately. The theory of deliberate practice also emphasises the domain relevance of learning activities and it is argued by Ericsson (Ericsson, 2009) that practice activities are most effective for learning if they are specifically designed to develop aspects that need improvement and allow for feedback and repetition.

The practice of 'Action Learning' (Revans, 2011), or learning through doing in the workplace supported by colleagues, was identified by Revans as a process that helped people to solve ill-structured management problems with multiple potential solutions. Here the role of the teacher was to construct appropriate opportunities for this to happen. Whilst this might apply when students undertake a SIP this is not the case in the L&ES preparation activities.

The following key points emerge from the literature on professional expertise:

- deliberative expertise appears to be a good match with SIP skills
- expertise is a multi-faceted construct and includes different types of theoretical and practical knowledge including knowledge of the work context
- expertise is developed via experience: multiple experiences are required that are authentic in relation to the activity to be performed in practice and the context in which they happen,
- authentic experiences should be followed by feedback and reflection to develop an improved understanding before further experiences.
- aspects of deliberative expertise can be developed in HE programmes and in the workplace – with the relevance of the experience to activities in practice being critical

2.4.4 Graduate Employability

In this section, graduate employability literature is reviewed to identify relevant models, theories and frameworks that take into account different stakeholder perspectives. Key points relating to how graduate employability skills are developed were then extracted.

The Department for Education and Employment commissioned a literature review to develop a general definition and framework for Employability. This work (Hillage and Pollard, 1998) defined four strands of individual employability: 'assets' - the knowledge, skills and attitudes possessed, the way they are used, how they are presented to employers and the context within which an individual seeks work.

The HEI perspective developed by Knight and York (Knight and Yorke, 2004, Knight and Yorke, 2002) was introduced in section 2.3. A refined definition of Graduate Employability was developed being "a set of achievements – skills, understanding and personal attributes – that makes a graduate more likely to gain employment and be successful in their chosen occupations……." (Yorke, 2006).

The Government and HEI definitions have aspects in common; they both identify individual knowledge and skills and cover how they are used to gain and perform in a job. A difference though was attitudes versus personal attributes, where attributes or personal qualities (E), used in the USEM model (Knight and Yorke, 2002) described below, represent a broader and deeper set of individual aspects.

In the USEM model, Personal Qualities (**E**) describes a persons' beliefs that they can make an impact on a situation. This was a significant feature of the model as it fed the U, S and M components, see Figure 8. The term Subject **U**nderstanding (**U**) was preferred to degree knowledge as this also includes knowledge related skills such as critical thinking and information handling (Knight and Yorke, 2004). The **S**killed Practice (**S**) component consists of both subject and 'generic' skills and the term was chosen to capture their view that skills were context specific, not easily transferable, and assessed with difficulty. The **M**etacognition (**M**) component was a measure of self-awareness: what you know, can do and how you learn.

The representation of the USEM model in Figure 8, whilst illustrating the relationship of the components does not reflect the depth within the components or the complexity of Employability as a construct. It was presented as a heuristic model to guide practice but there is little evidence to suggest it is being used. Whilst there are many possible explanations, in applied discipline programmes such as engineering, the course design would seek to meet the specific requirements of professional body rather than look to a general academic model.

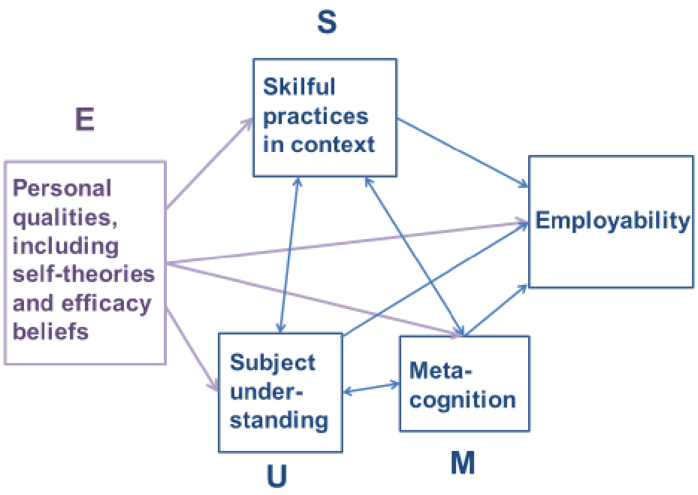


Figure 8. USEM Model of Employability (Knight and Yorke, 2002)

An analysis of how the USEM model (Knight and Yorke, 2004) relates to SIP skills not unexpectedly reveals the greatest linkage with **S**. To develop a better theoretical understanding of teaching skills the USEM model warrants further exploration as this model indicates that the U, M and particularly the E components all feed into skilful practices. This is carried out later in this section.

Later work on employability takes a career development perspective. An example is the CareerEDGE model (Dacre Pool and Sewell, 2007) developed, in part, to address difficulties of student use of the USEM model for career development. The authors adapted a previous Career Development model and although there appears to be a large overlap with USEM in terms of content, the underpinning positioning of the E aspects is lost.

With a focus on the employability skill needs of Engineering graduates, a wide range of academic and non-academic literature claiming to demonstrate employer skill needs, particularly related engineering and manufacturing was reviewed (Markes, 2006). It found that it was impossible to undertake meaningful comparisons or draw conclusions because of the range of terminology, and that many of the surveys lacked detailed skills breakdowns so the skill descriptions were very general so were of limited use in planning training.

A key concern with the models and frameworks discussed so far was the connection of theory with practice. This was partly because they are general and not specific to a particular discipline or working context and a direct connection or explanation on how they are applied in practice was not included.

Focussing on Engineering, Trevelyan (2009) found that contemporary writers on Engineering Education predominantly subscribed to a technical problem-solving and design view of engineering practice. However his research on engineering practice found that cooperative social relationships, which enable technical coordination and facilitate the application of distributed expertise, dominate practice (Trevelyan, 2010). He also suggests that narrowly focussed models of engineering communication need to be broadened to reflect the range of communication skills needed in practice (Trevelyan, 2009b). Trevelyan argues for a theoretical framework of engineering practice (Trevelyan, 2014) to assist a wide range of stakeholders in understanding what engineers do particularly if it incorporates both technical and social aspects of engineering.

Work across the academic – graduate employment boundary in Australia, involving all key stakeholders, has enabled academics to understand what graduates from a particular discipline are expected to do in practice (Dowling and Hadgraft, 2012) and across different discipline contexts.

The resulting three-dimensional view of graduate practice capabilities recognises that a graduate task was typically a combination of technical, process and generic capabilities (Dowling and Hadgraft, 2012) as illustrated in Figure 9. The work also recognises the differences in practice contexts, and whilst process and generic capabilities can be applied across all contexts, the technical capabilities may or may not be relevant (Dowling and Hadgraft, 2013). When done on a discipline basis this work can inform the curriculum of a discipline specific degree (Dowling and Hadgraft, 2012) and a better understanding of graduate tasks in industry by academics should enable then to make better connections between what was being taught and how it might be used in practice. This model does recognise some social aspects (Trevelyan, 2010) in the generic capabilities with communication being the largest of these categories, however these are far less represented than the technical and process aspects. Further concerns surround the rate of change and volume of the technical knowledge e.g. due to the fast changing digital world and the ever expanding pool of technical knowledge.

In terms of the implications for teaching activities that support skill development, it would suggest the use of learning activities to simulate graduate tasks requiring the application of multiple capabilities at the same time.

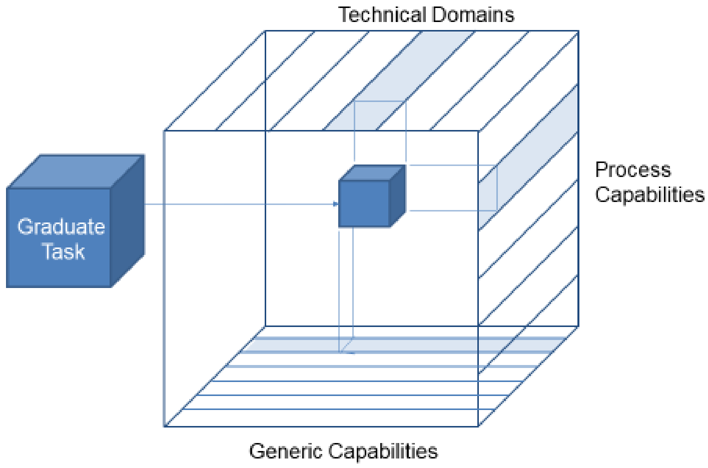


Figure 9. Graduate Capability Cube

The Define Your Discipline process (Dowling and Hadgraft, 2012) that generates discipline models was claimed to be an effective way of defining what graduates should be able to do for all stakeholders, at a National rather than individual HEI level (Dowling and Hadgraft, 2012). To inform ISMM, a multi-disciplinary model of practice 4 to 6 years after graduation would be required and no evidence of such a model has been found.

The USEM model is now examined further to identify contributing models and theories that directly support the teaching of skills. Skilful practices are context specific (Knight and Yorke, 2004) and involve both procedural knowledge and the deployment of disciplinary understanding U. Thus developing skills must be done on appropriate problems and in relevant contexts.

Eight theoretical E contributions are listed (Knight and Yorke, 2004) – see Table 12. Others are implied, but not listed or referenced. Each is considered in turn below to determine relevance for teaching skills.

Contribution	Theorist (s)
Fixed and malleable self-theories	Dweck (1999)
Learning and performance goals	Dweck (1999)
Performance goals subdivided into approach and avoidance versions	Dweck (1999) followed by Pintrich (2000)
Practical intelligence	Sternberg (1997)
Locus of control	Rotter (1966)
Self-Efficacy	Bandura (1997)
Learned Optimism	Seligman (1998)
Emotional intelligence	Salovey and Mayer (1990), Goleman (1996)

Table 12: 'E' Theoretical Contributions

Self Theories – Dweck (Dweck, 1999) found that if a student has a malleable self-theory of intelligence i.e. a belief that intelligence can be cultivated by learning, then they are more likely to be open to learning new things. Alternatively, if students believed their intelligence was fixed they focus on demonstrating that they have enough and avoid situations where they might be found lacking. Having a malleable self-theory was more likely to support skill development, so in terms of teaching it is important to demonstrate to students that attributes can be developed.

Learning and performance goals are connected with the previous theory as Dweck (Dweck, 1999) found that 'learning' goals prevail more often when students have a malleable self-theory and 'performance' goals when students have a fixed self-theory. Pintrich (Pintrich, 2000) found that 'performance' goals could be subdivided into 'approach' goals, where the motivation was to demonstrate mastery or 'avoidance' goals where the motivation was to avoid demonstrating inadequacy. In terms of developing skills, learning by doing is important, so having either a 'learning' or 'approach performance' goals will help them do this.

The concept of practical intelligence (Sternberg and Grigorenko, 2000) or practical problem solving (Hedlund and Sternberg, 2000), has a significant resonance with a SIP as described in section 1.2. It comprises multiple skills including, recognising and defining problems, allocating resources to solving problems, and evaluating potential solutions. Practical intelligence was distinct from academic intelligence (Sternberg and Grigorenko, 2000) with the majority of the practical intelligence development occurring in adults through real life experience and problem solving. In terms of teaching practical problem solving skills it is important to provide students with practice problems that have the characteristics of practical rather than academic problems – see Table 1.

The notion of 'locus of control' concerns the extent to which people see themselves as being able to control events or as being controlled by others. This was seen to apply to undertaking a SIP at a general level and not specifically to the development of skills.

Self-Efficacy (**SE**) is the belief in one's ability to succeed in specific situations or accomplish a task and is developed through experience. Four ways of influencing efficacy development, in order of reducing level of effectiveness, are identified (Bandura, 1995) as:

- mastery experiences – successfully completing a tough challenge
- vicarious experiences – observing peers achieve success in a tough challenge
- social persuasion – involves verbal encouragement
- enhancing physical and emotional states – supports the development of a positive mood which enhances self-efficacy

This would suggest that providing opportunities for both Mastery and Vicarious experiences should be effective in supporting skill development.

Learned optimism is the concept that having an optimistic outlook makes a difference to the way a person faces up to the challenges of employment and life in general (Knight and Yorke, 2004). This was considered of general relevance to the ISMM programme, but not directly associated with skill development.

The concept of Emotional Intelligence, although not new, was popularised by Goleman (Goleman, 1996). It concerns aspects such as knowing and managing your emotions, recognising emotions in others and handling relationships. Given the nature of a SIP, helping students to further develop their emotional intelligence should directly support the development of SIP skills. It should be noted that in 2006 Goleman divided his previous work into two parts separating out Social Intelligence (Goleman, 2006) as the intelligence related to relationships with other people with emotional intelligence focussing on self-management.

The final aspect of the USEM model explored in more depth was Metacognition, where Flavell's (Flavell, 1979) conception of metacognition is the basis. This comprises three aspects: strategic thinking, applying know-how to a task followed by reflection, and personal self-awareness. Students typically develop a level of metacognition through HE study without specific attention to it in the curriculum (Knight and Yorke, 2004).

Knight and Yorke argue that given the strong link to employability there was a case to deliberately include this in the curriculum. There is a clear link between Metacognition and SIP skills so building in opportunities for students to reflect post exercise is one example of how activities related to metacognition could be included.

Considering the graduate employability literature above, the following key points emerge:

- graduate employability is a complex construct made up of multiple aspects
- general models of graduate employability are difficult to apply in practice as they are not linked to a specific discipline, context or job
- the Capability Cube model describes graduate work tasks as a combination of three different types of capabilities and enables understanding across the HE – work boundary. However, a model relevant to ISMM was not found.
- The USEM Model offered insights into skills development with Efficacy Beliefs (E) and Metacognition (M) being directly linked
  - E was positioned as the foundation of employability, and theories relevant to developing SIP skills were practical, social and emotional intelligence, self-efficacy beliefs and self-theories. Experiences are important in developing practical intelligence and self-efficacy.
  - All aspects of Flavells conception of M were found to be applicable to developing SIP skills

2.4.5 Teaching and Learning in HE

The final academic field reviewed was Teaching and Learning in HE to identify the philosophies, theories and models most relevant to teaching SIP skills.

Outcomes-based teaching and learning is a student centred model of teaching (Biggs and Tang, 2007), where teaching supports learning. Student centred teaching is underpinned by either a phenomenography or constructivism philosophy (Biggs, 2003). Phenomenography is the view that teaching is a matter of changing the learners' perspective i.e. how they see the world and how they represent knowledge, whereas constructivism sees teaching as a matter of engaging students in active learning and building their knowledge in terms of what they understand. Constructivism was identified as the teaching and learning philosophy underpinning ISMM as it was based on active learning methods, so constructivism rather than phenomenography based work on teaching and learning was the ongoing focus.

Biggs, who holds a constructivism view (Biggs, 2003), further developed a Presage, Process, Product model of HE teaching & learning to provide a holistic system model (Biggs, 2003) shown in Figure 10. This builds on previous work (discussed later) and illustrates the connectedness of the different elements with the darker blue arrows representing the general direction of the effects. For such a system to work effectively then all elements need to be aligned. Biggs states that the critical components of the system are: the curriculum, teaching methods, assessment procedures and teaching climate both at classroom and institutional levels (Biggs, 2003).

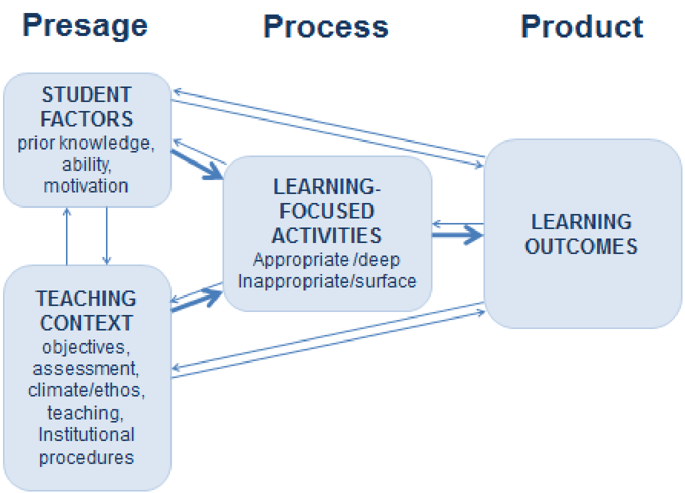


Figure 10. Biggs 3P Model of teaching and learning, Biggs (2003)

Combining an aligned approach to teaching with a constructive philosophy generates the theory of Constructive Alignment (**CA**) (Biggs, 1996). Biggs recognises that the principles behind constructive alignment are not new - just overlooked – surprising as they are clearly stated on page one of the ‘Basic Principles of Curriculum and Instruction’ first published in 1949 (Tyler, 2013). Biggs presents his theory as crucial to the delivery of quality learning in HE. This theme was explored by others such as Stephenson (Stephenson, 1992) who discusses the requirement of efficiency in production from a HEI’s perspective – quality has to be achieved within a reasonable resource allocation – a key consideration with today’s tight teaching budgets and pressures on academics time.

The Biggs 3P model is a combination of the work of Dunkin & Biddle who established the basic four variable model against a presage, process and product timeline (Dunkin and Biddle, 1974), and the work of Marton and Säljö on deep and surface approaches to student learning (Marton and Säljö, 1976b, Marton and Säljö, 1976a). The two most significant changes from Dunkin & Biddle's model are the addition of the feedback arrows making this a 'system' and that 'Teacher' factors are reduced in prominence only appearing as one item 'teaching' in the Teaching Context group of variables.

Marton and Säljö identified that students demonstrate either a surface or deep approach to learning when given a particular task. Surface approaches are when students focus on demonstrating the 'signs' of learning e.g. learning a few facts, rather than in a deep approach, where a student wants to understand a topic in depth and how it relates to other aspects of their knowledge. It was important to note that these approaches are not characteristics of the students. They decide an approach taking into account factors such as time available. When students engage in deep learning they are much more likely to achieve Intended Learning Outcomes (**ILOs**) (Biggs and Tang, 2007). Biggs believed that the essence of good teaching (Biggs, 2003) was maximising the chances that students adopted a deep rather than a surface approach to learning. This located the theory of surface and deep learning firmly in CA theory.

The definition of teaching is now expanded to 'engaging students in activities that enable them to achieve ILOs, taking into account Institutional policies and the resources available'.

CA can be represented as a model (Biggs, 2003) with two interrelated systems – the teaching system and the learning system – see Figure 11.

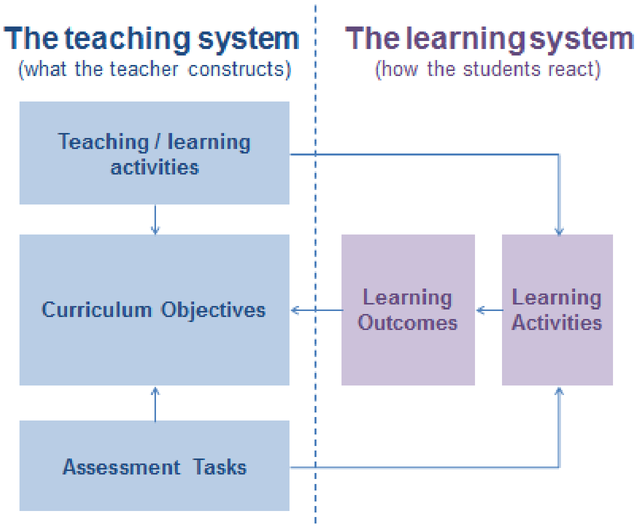


Figure 11. Constructive alignment theory presented as dual interrelated system

A further focus on the teaching system (Biggs and Tang, 2007) provides a general framework for teaching which constitutes three parts: teaching/learning activities, intended learning outcomes and assessment tasks. This is shown in Figure 12.

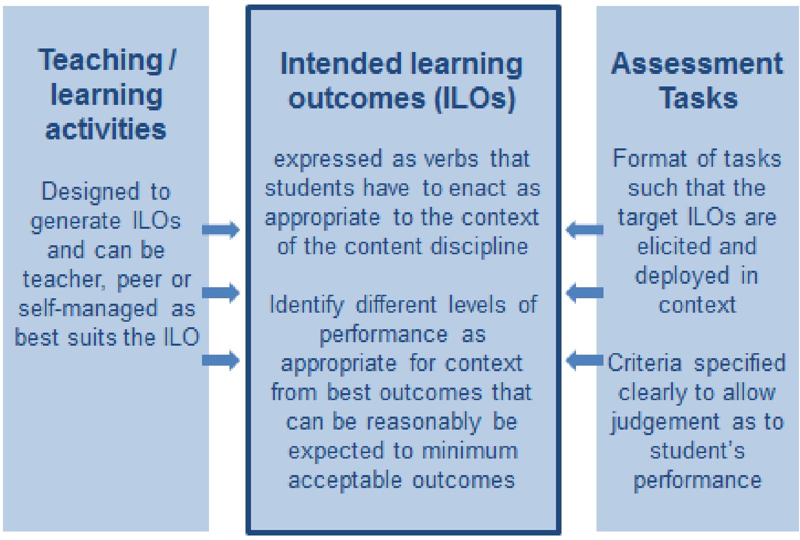


Figure 12. General Framework for Teaching – adapted from Biggs and Tang (2007)

Neither of these representations includes an explicit link to teaching climate that Biggs highlights as a critical component of the system and was included in the 3P Model. There is also an inconsistent use of terminology across the three models which may reflect the different viewpoints being demonstrated but leaves them open to misinterpretation. For example, the dual system model explicitly refers to curriculum objectives that might suggest that the system was designed to support the teaching of declarative or propositional knowledge.

Biggs and Tang argue that the CA model can be used to teach professional or 'functioning knowledge', however the teaching and learning activities need to be different than when teaching declarative knowledge. For example if there is an ILO of 'apply xxx to yyy' then students must have the opportunity to do this in practice rather than just listening to someone talk about applying xxx to yyy.

Ambrose et al describe seven research-based principles of HE teaching and learning, taking an outcomes based approach with a constructivism philosophy, covering both knowledge and skills (Ambrose et al., 2010). Of particular resonance is the principle about skills "To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned." This is presented in the context of students having to perform complex tasks where it is necessary to practice combining knowledge and multiple skills to develop fluency and automaticity.

A comparison of the above with the 3P Model Figure 10 demonstrates that these characteristics describe many of the elements in the 3P model in more detail.

Each of the four critical components of the teaching and learning system previously listed i.e. the curriculum, teaching methods, assessment procedures and teaching climate are now be discussed in turn. Please note that 'curriculum' has been substituted with ILOs as these drive what is 'taught' and the term does not suggest either declarative or functional knowledge.

Intended Learning Outcomes (ILOs)

An ILO statement should describe what, and how well, a student should be able to do something at the end of a period of teaching and in a way that enables recognition on whether that ILO has been achieved (Biggs and Tang, 2007).

Bloom identified six levels of learning objectives in the cognitive domain of: knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, 1956). In the rework of this taxonomy (Anderson and Krathwohl, 2000) the outcome was made more recognisable with the level descriptors being reworded into the 'doing' words of remembering, understanding, applying, analysing, evaluating and a new highest level of creating was added. The level of learning outcome has been linked to deep and surface approaches to learning (Biggs and Tang, 2007) with deep approaches appearing to span five levels from remembering to evaluating and surface approaches appearing to span remembering and some aspects of understanding. The implication for teaching was that to stimulate deep learning, a range of learning outcomes should be defined at different levels of difficulty. It should also be noted that the higher levels of learning relate to functional knowledge as opposed to declarative knowledge.

Teaching and Learning Activities

Having defined ILOs, the teacher needs to design the learning activities to enable students to achieve them. As previously stated, constructivism is based on active learning that was first defined as "anything that involves students in doing things and thinking about the things they are doing" (Bonwell and Eison, 1991). This definition was narrowed to "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes” (Felder and Brent, 2009). It could be argued that taking notes counts as active learning if students are thinking about what they are doing. The important thing to note was the type of activity was not constrained. In a review of research, empirical support for active learning was found to be extensive (Prince, 2004) but active learning was best considered as an approach rather than as a specific method. Constructivist methods are not without challenges and particularly in the case of novices learners, who must be guided through learning tasks to demonstrate what to do and how to go about it (Kirschner et al., 2006) .

Active learning ‘methods’ that could support the development of SIP related skills in a classroom-based setting were identified as: cooperative learning, problem based learning, project based learning, real-world simulations or exercises, case-based learning and discovery learning (Biggs and Tang, 2007, Goodhew, 2010)

Cooperative learning involves students working in groups to complete tasks collectively toward academic goals (Prince 2004). According to Johnson and Johnson's meta-analysis (Johnson et al., 1998), students in cooperative learning settings compared to those in individualistic or competitive learning settings, achieve more, reason better, gain higher self-esteem, like classmates and the learning tasks more and have more perceived social support. There are problems with group work (Biggs and Tang, 2007) such as when students focus on their specific task and not on the whole group task and when they do what they are best at rather than developing new skills. One way to mitigate this is by assigning roles and adding another element of assessment to provide a holistic view such as a reflective journal.

Problem based learning (PBL) consists of the use of discipline relevant, real-life problems for students to work on in small teams (Barrett and Moore, 2011, Edstrom and Kolmos, 2014). A typical use of PBL would the presentation of the problem at the start of a learning process rather than after a series of lectures of workshop. Whilst PBL is not a direct match with the structure or context of the learning process in comparison to SIPs, there will be overlaps given the similarities of the constituent aspects. One aspect is discovery learning where learners obtain knowledge by forming and testing hypotheses – a deliberative process already mentioned in the previous section.

Project-based learning, denoted PjBL (Graham and Crawley, 2010) has been defined as "..begins with an assignment to carry out one or more tasks that lead to the production of a final product – a design, model, a device or a computer simulation" (Prince and Felder, 2006). A key feature of PjBL is the focus on a fixed deliverable. In a SIP deliverables are not fixed – some are suggested in the initial brief, but challenging these and defining the problem is a key part of a SIP.

Exercises or simulations related to practice are able to provide a wide range of skill development opportunities (Jennings, 2002, Goodhew, 2010). It is noted (Goodhew, 2010) that these are particularly effective for learning related to complex situations and that they tend to be rare in practice due to the time required to develop them. A recent example of practice-orientated learning in an environment close to industrial reality is LeanLab (Karre et al., 2017). The "assembly" challenge in section 2 is similar in nature to Exercise 3 described in Chapter 2 Table 8 in which the students are set the challenge to determine a faster way of assembling a real item and invited to design and build devices / jigs to support this process.

Case-based learning can take various forms including narratives describing a real-life situation and is a method that has been used extensively related to professional education (Biggs and Tang, 2007). A particular strength is bringing the real-world context of the case into the learning experience – a challenge is being able to adequately represent this.

It is noted that the teaching role related to active learning is designer, organiser and then facilitator which are different to the more traditional lecture design and delivery skills associated with teaching declarative knowledge. To do this effectively it may be necessary for the teacher to have experience of relevant real world contexts.

The characteristics of effective learning experiences that support the development of expert professional practice for engineers during HE, including the development of skills or 'functioning knowledge' was synthesised (Litzinger et al., 2011) into a table containing thirteen different aspects. This is presented in Table 13.

Instructional Practices that Create Effective Learning Experiences
Affective • Arouse interest for students of contrasting abilities and goals. • Provide stimulating, interesting, and varied assignments that are within the range of students' abilities but challenge them to reach for the top of that range. • Make connections to students' interests and intended careers.
Meta-cognitive • Build self-regulative abilities by explicitly teaching students about them • Promote reflection to enhance attention to meta-cognitive aspects of learning • Provide timely and constructive feedback on the learning processes so students understand what they know and can do well, and what they need to improve.
Cognitive • Engage students' prior knowledge through selection of learning tasks that are at appropriate levels of difficulty • Promote deep engagement with content through assignment design and tasks that reuire meaningful integration with peers • Require students to integrate their knowledge and skills to complete increasingly complex assignments • Provide support to "scaffold" student learning, especially for assignment that require integration of knowledge and skills. • Use assessments that make students' thinking processes apparent so their level of understanding can be assessed. • Provide timely and constructive feedback that focusses on development of all elements required for expert-like performance: conceptual understanding, component skills, professional skills, and the integration of knowledge and skills. • Use summative assessment techniques that evaluate and reward all elements required for development of expert-like performance.

Table 13: Characteristics of effective learning experiences – Litzinger et al. 2011

In summary, there are multiple teaching methods that support skill development. Of the methods reviewed the combination of cooperative learning and exercises was the best match with current L&ES practice however there were overlapping aspects with the other methods discussed.

<u>Assessment</u>

Assessment is the mechanism that enables both teachers and students to determine if the ILO has been achieved or if progress has been made towards it. As shown in Figure 12, the format of the assessment tasks should enable the target ILOs to be elicited and deployed in context and clear criteria specified to allow judgement as to the level of student's performance.

Biggs argued that the assessment of functioning knowledge, taught on profession related programmes, was in principle easier than the assessment of declarative knowledge (Biggs and Tang, 2007) as ILOs were often associated with performing a task in a professional context. In practice there are many difficulties, two being identification of the appropriate skills to be assessed adopting an appropriate assessment mechanism. An example being provided on the introduction of scrum techniques (Stawiski et al., 2017) where they set out to develop self-awareness, collaboration and problem solving skills but measured leadership behaviours via student self assessment.

Multiple methods of assessing functioning/professional knowledge are suggested (Biggs and Tang, 2007) and those relevant to the teaching SIP skills in the class room were identified. Those already used in developing SIP skills involve students in:

- making presentations
- undertaking group projects to learn cooperative / team-working skills
- peer & self-assessment of tasks. To be effective, good review criteria are needed and it has been found to work better with advanced students rather than novices, as novices lack awareness of what ‘good’ looks like.
- case study – ideal way of applying skills in practice using a relevant case. Whilst the activities in the Induction Module are described as exercises they are based on real scenario’s and businesses so could be considered case studies

Those not used in SIP skill development are:

- recording critical incidents – although only mentioned in a workplace setting this could be adapted for the classroom exercises
- reflective journals – good for application of content knowledge, professional judgement, reflections on decisions made and problem solving
- work portfolio – where a student can place their best work for assessment to demonstrate they have achieved their ILO’s. This is particularly good for summative assessment, where there are clear ILO’s and for demonstrating unintended learning outcomes.
- In PBL a problem solving assessment method is the ‘triple jump’ procedure (Mtshali and Middleton, 2011) which enables different stages of the problem solving process to be assessed. This detailed type of assessment is contested

by Kingsland 1995 who considers that summative assessments should be performance based, holistic and provide scope for students to input own decisions and solutions. It could however be valuable in formative assessment to enable the development of different aspects of the problem solving process.

Formative methods of assessment require tutors to be able evaluate and provide feedback to the students. This process can be time consuming and finding effective ways to do this is essential, particularly with large classes.

Teaching and Learning Climate

The classroom climate has a significant impact on students' learning with some aspects likely to stimulate deep learning and others surface learning. Climate is established through both formal and informal interactions with the teacher (Biggs and Tang, 2007). Aspects likely to stimulate deep learning are:

- trusting the students to take charge of their learning, giving them sufficient time and opportunity to engage in appropriate learning activities,
- creating an ethos where making mistakes is a normal part of the learning process and formative feedback is provided to enable students to improve,
- providing a well-structured knowledge base and encouraging reflective practice and self-monitoring (Biggs and Tang, 2007).

The aspects above have been identified as contributing to skill development, with the exception of providing a well-structured knowledge base. This links back to constructivism mentioned at the beginning of this section 2.4.5, that teaching is a matter of engaging students in active learning and building their knowledge in terms of what they understand. It is important to help students connect knowledge, this may involve restructuring existing knowledge to be able to connect with new knowledge as well as make interconnections between different types of knowledge.

The following key points emerge from the teaching and learning literature:

- The principle of CA and the associated 3P Model can be equally applied to teaching skills as well as teaching declarative knowledge, however the associated teaching activities and assessment methods for each will differ.
- A range of ILOs are required to stimulate deep learning approaches – functioning knowledge ILOs are by their nature higher level ILO's than those

related to declarative knowledge as they typically require both types of knowledge to be applied together.

- Active learning methods for developing skills in a classroom were identified as cooperative learning, problem and project based learning, real world simulations or exercises, case-based learning and discovery learning.
- Assessment of practical abilities was easy in principle but time consuming in practice. Multiple different assessment methods were available some of which were used in relation to SIP skills.

2.4.6 Summary - academic perspective

This section draws together insights from the three fields of literature reviewed to capture the implications for the development of SIP skills. From the field of Teaching and Learning the key findings are listed immediately prior to this section.

From the field of Professional Expertise it was found that;

- SIP skills aligned with 'deliberative expertise', argued to be a generic high level skill set that is non-context specific as it includes activities to characterise the context and then determine an appropriate approach to a problem.
- expertise is multi-faceted, combining theoretical and practical knowledge with judgement and (in many cases) a capability to work with people.
- expertise can be developed in both HE and workplace environments through 'experiential learning' - where multiple experiences are provided that are authentic in relation to the learning objective and the context in which they happen. These experiences should be facilitated such that they are followed by feedback and reflection to develop an improved understanding before further experiences.

Findings from the field of Graduate Employability reinforce that in practice any task is the combination of different sets of knowledge and skills in a particular context and that experiences are important in developing skills. In addition, the development of skills was directly influenced by E and M abilities and of particular relevance to developing work-related skills are practical, emotional and social intelligence, self-efficacy, being motivated to learn, open to learning new things and being prepared to learn by doing and reflecting on experience.

The key theories and models that cover the problem domain were seen to be deliberative expertise, experiential learning and constructive alignment. These theories overlap with many of those associated with the E and M abilities of Graduate Employability. Deliberative expertise overlaps with practical, emotional and social intelligence. Being motivated to learn and open to learning new things connects with constructive alignment and being prepared to learn by doing and reflecting on experience overlaps with experiential learning. The one theory where there is only a partial overlap is that of self-efficacy where the mastery and vicarious experience elements are new and also connect strongly to experiential learning. Thus, it is proposed to add this as a fourth key theory.

With the key theories identified and the practice described, the next part of the problem formulation is diagnosing the problem.

2.5 Diagnosing the problem

The practice diagnosis was undertaken in section 2.3. It was determined that: the teaching activities and formative assessment mechanisms applied in the Induction Module appear to be effective in developing a students' SIP skills, there are difficulties in articulating ILOs and the specific skills to be developed, some components of the SIP summative assessment were not appropriate.

The academic diagnosis involves applying the theories and models identified in the academic grounding of the problem to the practice to determine if any new anomalies or insights emerge. These will be applied in the following order, deliberative expertise, experiential learning, self-efficacy and constructive alignment.

Deliberative expertise – there would appear to be good high level alignment with the description of SIP skills but as both are only captured at a high level no new learning emerges.

Experiential learning (EL) – from the description of practice in 2.3.1 it is clear that there are multiple experiences, followed by feedback and some time for reflection. So, it would appear that there is good match between the theory and practice but this diagnosis is only undertaken at a very high and superficial level as the actual practice has not been observed so no additional insights are achieved.

Self-Efficacy (SE) – the theoretical description of mastery and vicarious experiences appears to align with the practice description in 2.3.1 and support the use of experiences as essential to developing skills. However, the exercises might be specifically facilitated in practice to enable some mastery experiences to be achieved. It was not clear whether the exercises were set at a level that was too challenging, or whether this facilitation just enables variations across cohorts to be managed.

Applying **Constructive Alignment (CA)** provided insight into why the L&ES was effective. The learning activity and the formative assessment tasks were perfectly aligned, as they were the same. It is speculated that the ILOs become clearer to the students through observing what 'good looks like' through mastery performances or through the feedback provided. If so, then the L&ES was a constructively aligned. Further diagnosis should be possible after observing the practice.

With the diagnosis task completed as far as possible without observing the L&ES, the final problem formulation task of resolving the problem was undertaken.

2.6 Resolving the problem

Resolving the problem is different for research and practice (Van de Ven, 2007). In terms of research, the solution was most commonly a specific research question that can enable a better understanding of the problem where relevance, size and scope are the most important selection criteria. In terms of practice, the purpose was to recommend and implement solutions that might solve specific problems identified. Only the research aspects are reported.

The L&ES was intended to develop SIP skills through the use of facilitated HE-based experiences relevant to work tasks. A better understanding of this practice is required as it has the potential to inform the broad problem of graduates having insufficient work skills.

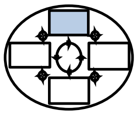
Reflecting on the above diagnosis, a number of relevant research questions could be posed including:

- What are the essential components and characteristics of HE based facilitated experiences relevant to the work context?
- What do ISMM teachers do to facilitate the teaching of SIP skills in a HE classroom setting?
- What tasks are carried out when undertaking deliberative processes in a manufacturing business context?
- What happened during the L&ES to support the development of SIP skills?

Of the above questions, ‘What happened during the L&ES to support the development of SIP skills?’ was selected for an exploratory study. This would enable the skill development practice to be observed and the grounding of the problem to be checked. It was also practical as the L&ES takes place in Cambridge, the timing aligned with PhD study requirements and there were sufficient resources for this research.

Having completed the problem formulation stage of the ES Method and achieved the desired outcome of identifying a question that was relevant and appropriate in size and scope, the next stage of Theory Building was addressed.

CHAPTER 3: BUILDING A CONCEPTUAL SKILLS DEVELOPMENT THEORY

Chapter 3	Research Round 1	Theory Building ES Research Activity 	A plausible skills development theory is built from which a conceptual skills development framework (CSDF) is constructed to answer the research question identified in Chapter 2 and test the proposed theory.

The purpose of theory building was to develop a plausible theoretical lens that can support the answering of the research question identified (Van de Ven, 2007). Theory building is closely linked to problem formulation activities requiring a deep familiarity with the problem domain (Van de Ven, 2007).

Theory building involves three activities: creating, constructing and justifying a theory (Van de Ven, 2007). In practice it is an iterative process, between the above activities and multiple research rounds required to develop a final theory (Van de Ven, 2007).

In this chapter, a skill development theory is created, constructed and justified drawing on three different, but overlapping, theories or models that are specifically related to developing skills identified in Chapter 2. The new theory is represented as a system model which highlights the complex nature of skill development. This model is then translated into a simpler analysable format, a conceptual skill development framework, for testing the theory (Shehabuddeen et al., 1999).

3.1 Creating the theory

Creating a theory uses an abductive reasoning process, trigged by an anomaly, to select a plausible solution that might resolve the anomaly (Van de Ven, 2007).

In this case, the anomaly was the successful skills development practice in the Induction Module because it produces results that contradict the prevalent view stated in Chapter 1 that HEI's are not adequately preparing students for the world of work. Drawing on the problem formulation in Chapter 2, a plausible explanation of how SIP skills are developed during the L&ES which has the potential to become a Skills Development Theory (**SDT**) was '*multiple work-relevant experiences, appropriately facilitated/taught and related to a specific set of work skills enables students to learn these skills and subsequently deploy these in practice'*.

3.2 Constructing the theory

Constructing a theory uses a logical deductive reasoning process to identify concepts or events, the relationships between them, the associated the boundary conditions, and the reasons for the relationships (Bacharach 1989). Taking the ‘potential theory’ above, there are three high level concepts: work-relevant experience, appropriate facilitation/teaching and a specific set of work skills.

From the academic diagnosis in Chapter 2, the three main theories that contribute to skill development are Experiential Learning (EL), Constructive Alignment (CA) and Self-efficacy (SE). How these theories relate to each other will be explored first.

The 3P Teaching and Learning Model shown in Figure 10 was the preferred model of CA because it identifies a broader range of concepts and the relationships between them than either the dual integrated system (Figure 11) or the teaching framework (Figure 12).

The author proposes that both EL and SE can be nested within CA and the case for this is presented below. There have been a number of studies on EL, of which some were reviewed in Chapter 2. In a review by Moon (Moon, 2004), she found that EL involves the following components;

- an ‘active’ doing phase or **experience** that forms the material of learning that is not usually taught
- **reflection** – either deliberately or not deliberatively
- a mechanism for **feedback**
- a formal **intention to learn**

An **experience** with **reflection** and **feedback** was seen to fall within the ‘Learning Focussed Activities’ box of the 3P model and the formal **intention to learn** connects with student motivation in the ‘Student Factors’ box.

Bandura suggests four methods for supporting the development of self-efficacy (Bandura, 1995): mastery experiences, vicarious experiences, social persuasion and enhancing physical and emotional states, as described in 2.4.4. The mastery and vicarious experiences are considered to fall into the ‘Learning Focused Activities’ box, with social persuasion relating to student motivation and creating a positive mood related to the climate/ethos aspects in the ‘teaching context’ box.

Having established how EL, SE and CA relate to each other, the connections between the proposed theory, set out in section 3.1, and CA are compared. The 'multiple' aspect of experiences was not captured explicitly in the 3P Model possibly because it is a general model covering the teaching and learning of both knowledge and skills. To capture the components of EL, SE and build in the 'multiple' experiences the CA model needs adapting to work at a more detailed level and focus on skills.

In adapting the model, 'multiple' experiences can be captured by stressing multiple cycles. Such cycles are considered to take in all components of the CA model as the teaching objectives and associated ILOs should progress through each cycle as the specific skill set develops. The components of EL and SE are not currently represented and can be added to the 'learning-focussed activities' box. Working at this more detailed level and from a teaching perspective it is argued that there are a number of 'givens' that a teacher cannot directly influence when teaching skills – these being student prior knowledge, ability and institutional procedures.

Adjusting the CA Model an initial representation of this skill development theory is shown below in Figure 13.

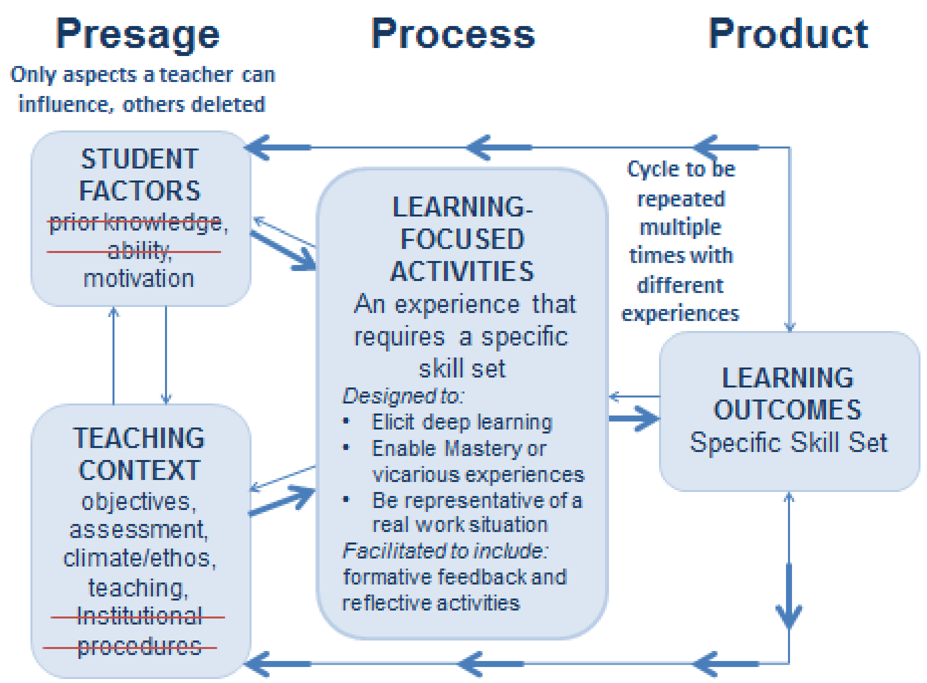


Figure 13: Conceptual Skill Development Model - Initial Representation

The ‘learning-focussed activities’ box is now significantly expanded and would benefit from being split to emphasise the different types of components. Two different categories emerge:

- providing multiple experiences relevant to practice
- supporting learning from experience.

Both categories encourage a deep learning approach as they incorporate a range of higher level cognitive activities (Biggs and Tang, 2007) ensuring that a deep learning approach was embedded in both.

The original ‘teaching context’ box was renamed as ‘create a learning environment to encourage deep learning’ to include other aspects that influence a deep learning approach such as assessment (Biggs and Tang, 2007). Here motivation was moved from the ‘Student Factors’ box and included as something the teacher can stimulate by making the case to the students that the skills to be learnt are both relevant and important. This eliminates the need for a Students Factors box in the new representation as the other two aspects were deleted, as not being something a teacher could influence – see Figure 13.

One aspect of the original ‘teaching context’ box was objectives. Given the problems identified in Chapter 2 on defining skills, combined with the need to define both objectives for the series of multiple experiences as well as each individual experience, it is proposed to treat this as a separate box: ‘describe skills’.

Using the above rationale the Conceptual Skill Development Model was redrawn in Figure 14 overleaf. The logic links remain those in the CA model with the bold arrows indicating the main direction of flow and emphasising a repeated application.

Returning to the proposed theory: *multiple work-relevant experiences, appropriately facilitated/taught and related to a specific set of work skills enables students to learn these skills and subsequently deploy these in practice*, and comparing this to Figure 14, it can be seen that:

- work relevant experiences are part of C,
- appropriately facilitated/taught has aspects in parts of A, B, C and D
- work skills are captured in A and also in E.

In conclusion, there would appear to be a reasonable fit between the proposed theory and conceptual skill development model constructed.

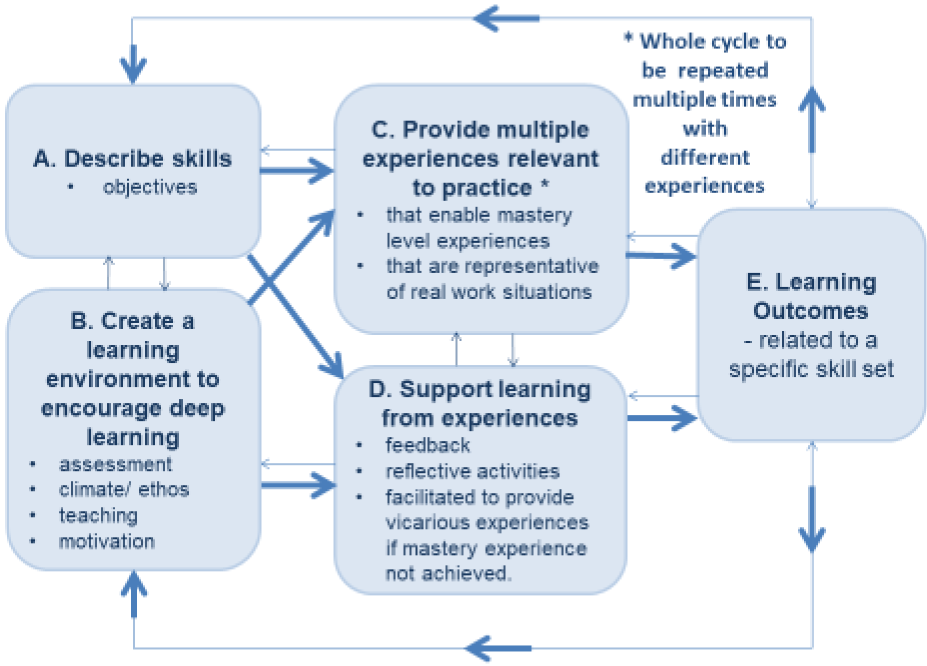


Figure 14. Conceptual Skill Development Model

The final aspect of constructing a theory is stating the boundary conditions, which are the limits at which the theory is expected to work. At this formative stage, it is suggested that the most limiting activity was likely to be providing experiences relevant to practice, as a HE environment may not be representative of a practice environment and a HE teacher may not have sufficient understanding of what would be appropriate practice activities. Another boundary will be the minimum number of experiences required to create the intended learning outcomes. It was thought unlikely that this would be the same for all skill sets, with more complex skill sets requiring more experiences. So this boundary would be determined through practice.

3.3 Justifying the theory

Justifying a nascent theory is the final part of the theory building process (Van de Ven, 2007) and it is necessary on both an empirical and a conceptual basis. Inductive reasoning is used to test the fit with the world on an empirical basis and rhetorical arguments are used to persuade on a conceptual basis.

On an empirical basis, no evidence was found to contradict the theory. On a conceptual basis the credibility of the new theory was strong as it was based on the established Constructive Alignment theory in which two further well established theories were integrated. As none of the three contributing theories were logically compromised in this integration, it was deduced that the new theory was also logically valid. Validity is the main criteria for the ES theory building stage (Van de Ven, 2007). With this seemingly achieved the new skill development theory requires conversion into a format suitable for testing.

3.4 Developing the Conceptual Skills Development Framework (CSDF)

The model in Figure 14 highlights the complex nature of skill development. To undertake preliminary testing and enable the research question, ‘What happened during the L&ES to support the development of SIP skills?’ to be answered, this model requires translation into a simpler analysable format, such as a conceptual framework, to provide a basis for comparison with practice (Shehabuddeen et al., 1999).

There are four main teaching activities identified in this model:

A. Describe skills
B. Create a learning environment to encourage deep learning
C. Provide multiple experiences relevant to practice
D. Support learning from experiences

Each of the above activities was considered in turn to identify a number of observable variables that could be included in a CSDF and which together would enable the research question to be answered and the theory to be tested. A danger was that the CSDF became too large to be a practical size when observing the teaching and recording the data.

3.4.1 Describe skills

From the literature reviewed in Chapter 2 defining skills was found to be problematic (Section 2.3.1). However, it was important to find a way of describing skills suitable for inclusion in the proposed skills development theory and for practice.

Two different approaches for describing professional skills were identified from the literature reviewed in Chapter 2, a knowledge based approach from the professional expertise literature where a broad definition of knowledge is used that encompasses practical knowledge required to perform professional skills, and a task based approach used in the Capability Cube model (Dowling and Hadgraft, 2012). A knowledge based approach was used because at the time the CSDF this was being developed, 2011, the Capability Cube Model was not published. The literature on professional knowledge was reviewed to establish if there were distinguishable components appropriate for the CSDF.

Eraut set out to develop a map of professional knowledge (Eraut, 1994), drawing upon prior contributions including:

- Ryle (1949) who re-trigged an ancient debate proposing a distinction between knowledge that and knowledge how
- Polanyi (1966) on tacit knowledge
- Schön (1983) who argued against the prevailing view that the most important aspect of professional knowledge was the specialised, firmly bounded, scientific and standardised knowledge associated with a particular profession. His view was that professional knowledge was a much broader construct and needed to include personal knowledge, tacit knowledge, process knowledge, and know how.

Eraut proposed three main categories of professional knowledge (Eraut, 1994):

Propositional knowledge – comprising of: discipline based theories and concepts, generalisations and practical principles associated with professional practice, and specific propositions about particular cases, decisions and actions

Personal knowledge - acquired from experiences, social interactions and trying to get things done

Process knowledge – which he defines as "knowing how to conduct the various processes that contribute to profession actions" (Eraut, 1994) and includes: procedural knowledge, how to access and use propositional knowledge and know-how. This category is also considered to include tacit knowledge - which although not explicitly stated by Eraut in this description was included in an example of process knowledge.

Eraut recognised this did not fully capture and codify professional knowledge attributing part of the problem (Eraut, 1994) to the field being under-conceptualised. Moving forward 20 years, these issues still remain (Young and Muller, 2014) but there is wide agreement now that professional expertise cannot be exercised independently of knowledge which is required to inform practice (Winch, 2014).

In a description of deliberative processes Eraut states that “they cannot be accomplished by just procedural knowledge, they require a unique combination of propositional knowledge, situational knowledge and professional judgement” (Eraut, 1994). Comparing this with the knowledge map above it can be seen that a new category of ‘situational knowledge’ appears, describe by Eraut as including the theories, perceptions and priorities of clients, co-professionals and other interested parties. His statement that “some might be explicitly stated – others may be hidden, implicit and difficult to detect” suggests that aspects of situational knowledge therefore could fall in any of his three broad categories of professional knowledge, propositional, personal and process described earlier.

Whilst a general model of professional knowledge is still not resolved, it was possible to identify four different types of professional knowledge proposed by Eraut that contribute to describing skills and which could be observed in practice these being:

- generalisations and practical principles associated with professional practice (Propositional Knowledge)
- specific propositions about particular cases, decisions and actions (Propositional Knowledge)
- how to do things – process steps (Process Knowledge)
- situational knowledge (Deliberative Processes)

Personal knowledge, tacit knowledge and professional judgement are also concepts mentioned by Eraut in relation to professional knowledge and deliberative processes.

It was proposed that each of the above was incorporated into the CSDF as separate aspects with situation knowledge considered a better fit with teaching activity C ‘provide multiple experiences relevant to practice’. A further measurable element of the time spent describing skills was proposed. This assumes that a longer and more detailed description would be better than a shorter, less detailed description.

So, the four aspects to be included in the CSDF are

- generalisations and practical principles associated with professional practice,
- specific propositions about particular cases, decisions and actions
- how to do things – process steps
- time dedicated to describing skills

3.4.2 Creating a learning environment to encourage deep learning

This second teaching activity picks up the remaining presage aspects and positions 'deep learning' in the 'presage' as well as the 'process' stage as discussed earlier in section 3.2. This repositioning was considered a better fit as Biggs and Tang (Biggs and Tang, 2007) state that teaching and assessment methods that support the explicit aims and intended outcomes are the most important aspect of encouraging deep learning.

Students adopt a deep approach if they determine that they need to fully engage in a task (Biggs and Tang, 2007). From a list of teaching factors that encourage a student to adopt a deep approach (Biggs and Tang, 2007) those relevant to teaching skills are:

1. eliciting an active response from students,
2. building on what students already know,
3. encouraging the need-to-know and instilling curiosity,
4. confronting and eradicating students misconceptions,
5. teaching and assessing in a way that encourages a positive working atmosphere where students can make mistakes and learn from them,
6. emphasising depth of learning and
7. using teaching and assessment methods that support the explicit aims and intended outcomes.

These factors work at different levels and across different parts of the proposed skill development model. As discussed at the beginning of this section, Biggs and Tang consider (7) to be the most important probably because this applies CA over the whole system. A further system level factor was (5) and it is argued that the remaining factors could be considered constituent parts of both (5) and (7).

Four factors were selected for the CSDF: (1) because active learning connected to EL and CA, (3) due to links with CA and some representations of EL, (5) connected with CA and SE and (7) aligned with CA.

Three factors were not selected: (2), (4), and (6). They were considered less important for developing professional skills as students may have little previous knowledge to build on and (4) and (6) were considered as part of being a HE teacher.

Eliciting an active response from the students (1) was interpreted as relating to all components of the teaching process. Experiences are by their nature active, but students still have to engage appropriately as well as with any post experience feedback and reflective activities. An observable aspect was the level of student engagement which can be monitored across all activities involved in the skill development process.

Encouraging the need-to-know and instilling curiosity (3) links directly with the motivation aspect of the CA model. This was particularly important when trying to teach something that students have little experience of. An observable aspect would be explanation by the teacher of why such skills are important and drawing students into the learning by posing questions that appeal to their curiosity.

Assessment was highlighted in both (5) and (7) as an important component. The more complex the construct being taught, the longer it takes to develop and the more challenging assessment becomes. In such cases priority should be given to formative assessment (Knight and Yorke, 2006) with summative, credit awarding, assessment only being made towards the end of an extended period of development. However challenging, it was important that key curriculum goals are assessed to be taken seriously (Knight and Yorke, 2006, Entwistle, 1996).

In terms of CSDF factors, it is important the summative assessment does not take place and that formative assessment should. This supports (5) the creation of a positive working environment where students can learn from mistakes. The experiences provided should require the skills to be taught to be demonstrated, thus making the teaching and assessment tasks perfectly aligned!

In summary, four observable aspects of creating a learning environment to encourage deep learning were identified for the CSDF:

1. summative assessment linked to demonstration of skills post development
2. formative assessment linked to development of skills
3. explanation of why the skill is important and how it is used
4. level of student engagement with all parts of the skill development process.

3.4.3 Provide multiple experiences relevant to practice

The third high level teaching activity in support of developing skills was providing multiple experiences that are authentic and relevant to practice. This emerged from the literature reviewed in section 2.4.3. It is important to clarify that these are mediated, as opposed to direct experiences (Moon, 2004), where students are provided with a simulation that has been captured in a way to support learning objectives.

No specific recommendations were found on the number of experiences required. This was not unexpected as the number was likely to differ depending on the type of experiences, the skills being taught and the individuals involved. It was important that the experiences provided are different to reflect the nature of professional work where each problem addressed will be unique in some way and to improve transfer of skills from one context to another. Thus, the number of different experiences is an important aspect to measure in the CSDF.

A second aspect to be tested was whether an experience was authentic and relevant to practice. The assessment criteria proposed to test this are: is the experience based on a typical, real-life situation and is it presented in an authentic way that simulates the practice situation in context.

A further aspect of providing experiences was ensuring they are 'mastery' experiences – see SE Theory in 2.4.4. Whilst these should result in a successful outcome as success builds efficacy beliefs (Bandura, 1997) the success must not be easy, requiring obstacles to be surmounted and effort to be applied. This involves the teacher in setting ILOs and learning tasks at sufficient level of challenge.

The teaching implication is that the experience should be designed such that 'mastery' experiences are achievable for some students and that delivery should be facilitated to ensure that some students achieve a mastery experience with the rest having vicarious experiences as this raises their belief that they can do that task too. It is noted, that aspect four below is also a key part of supporting learning from experience discussed in the next section.

So four aspects for the CSDF relating to experiences are:

1. number of different experiences,
2. experiences that are relevant and authentic,
3. with a sufficient level of challenge to produce mastery level experiences
4. facilitated to provide all with a vicarious experience if a mastery experience was not achieved.

3.4.4 Support learning from experience

The final high level teaching activity was supporting a student in learning from experience and specifically includes a review feedback and reflection – see Figure 14. These are reviewed in turn to identify four observable aspects for the CSDF.

3.4.4.1 Feedback

Feedback is part of the assessment process, being a consequence of an assessment task. Thus it should be connected to ILOs and based on clear criteria so students know how well they have performed (Biggs and Tang, 2007) and, it should enable a student to learn (Knight and Yorke, 2003).

Feedback is conceptualised in multiple ways: 'the provision of written comments or information' being a more literal view and, 'a dialogic process where learners make sense of information from varied sources and use it to enhance their performance or learning' being a broader, and more recent, view (Carless, 2015). It is the broader and more recent view that was taken in this study as this recognises the multiple purposes of feedback in providing retrospective and future-altering views of a learning task (Chetwynd and Dobbyn, 2011) as well as it being a process that is only effective if the learners engage with and use the information available to them.

Feedback can come from a number of sources including: lecturers, students, self, learning resources supporting the session e.g. worked solutions, books (Hattie and Timperely, 2007, Race, 2010) and in a different forms e.g. written comments, face to face verbal discussion or a video recording. One of the jobs of the teacher is to determine what different feedback mechanisms are both appropriate and efficient (Race, 2010).

Hattie and Timperley (Hattie and Timperely, 2007) investigated feedback effectiveness and found that the most effective methods focused on a task and how to do it better, and the least effective focussed on the student, such as praise. They then proposed a model (Hattie and Timperely, 2007) that distinguishes between four levels of feedback being:

Task Level – How well tasks are understood or performed

Process Level – The main processes needed to understand or perform tasks

Self-regulation Level – Self-monitoring, directing and regulating of actions

Self Level – Personal evaluations and affect about the learner.

In this model, the first three levels are about the task and the fourth is about the learner. Of these four, feedback at the ‘process’ and ‘self-regulation’ levels was found most effective, followed by the ‘task’ level and the least effective was the ‘self’ level.

Another aspect of effective feedback is timing. This is particularly important when developing skills using multiple experiences where feedback needs to occur prior to the next experience (Ericsson, 2009). Whilst there is a general view that this should be undertaken whilst the task is still clear in a students’ mind (Race, 2010), studies on whether feedback should be immediate or delayed have indicated that this should vary to take into account the simplicity and familiarity of a student with the task as well as the level of feedback to be given (Hattie and Timperely, 2007).

Reviewing the literature has revealed that feedback has many dimensions and there is a wealth of research into many aspects. The two aspects selected for the CSDF are, time allocated for prompt feedback after each experience but prior to the next experience and feedback focussed on the tasks with an indication on how they might improve. These were chosen because they were most relevant to support the initial testing of the proposed skill development theory.

3.4.4.2 Reflection

The following description of reflection has been adapted from Moon (Moon, 2004) to combine her common-sense, HE views to a skill development context. ‘Reflection is a form of thinking to achieve an outcome specified in terms of learning, action or clarification. Reflection is applied to relatively complicated, ill-structured ideas for which there is not an obvious solution and involves the further processing of knowledge and understanding that is already possessed.’

The above description demonstrates that reflection is something a student, rather than a teacher, does. A teacher can influence this by explaining the purpose and process of the reflection as well as requiring the outcome of reflective work to be in a form that can seen by others and assessed (Moon, 2004). Another teaching challenge is that students typically have a limited understanding of reflection, in terms of its value, what it means and how it is undertaken in practice (Moon, 2004).

Selecting just two 'teaching' aspects for the CSDF, having the opportunity for reflection between each exercise – on a timetabled or 'out of hours' basis – see section 3.2 and reflective activities should enable student learning were seen as most important .

In summary, the four observable aspects of supporting learning from experiences were:

1. time allocated to provide prompt feedback on each experience and prior to the next one
2. feedback focussed on the tasks being taught and indicative of how performance can be improved
3. time for student reflection on each experience prior to the next one.
4. reflective activities enable learning with respect to developing skills.

3.4.5 Capturing the CSDF

Aspects from the four high level teaching activities are collated into a Conceptual Skills Development Framework (CSDF) shown in Table 14 below.

	Teaching Activity Categories			
Aspect No.	**A: Describe skills**	**B: Create a learning environment to encourage deep learning**	**C: Provide multiple experiences relevant to practice**	**D: Support learning from experience**
1	Time dedicated to describing skills	Summative assessment linked to demonstration of skills post development	Number of different experiences	Time allocated to provide prompt feedback on each experience and prior to the next one.
2	Generalisations and practical principles associated with professional practice	Formative assessment linked to development of skills	Experiences that are relevant and authentic (Situational Knowledge)	Feedback is focussed on the tasks being taught and how performance can be improved
3	How to do things - process steps	Explanation of why the skill is important and how it is used	With a sufficient level of challenge to produce mastery level experiences	Time for student reflection on each experience prior to the next one.
4	Specific propositions about particular cases, decisions and actions	Level of student engagement with all parts of the skill development process	Facilitated to provide all with vicarious experience if mastery experience not achieved	Reflective activities enable learning with respect to developing skills

Table 14: Conceptual Skill Development Framework (CSDF)

3.5 Evaluating the CSDF

Whilst the CSDF covers the main aspects of all four teaching activities, 'support learning from experiences' seems under-represented perhaps because the literature on feedback and reflection is far more extensive. There were also some teaching aspects associated with 'creating a learning environment to encourage deep learning' covered in 3.4.2 such as 'confronting and eradicating students misconceptions' that would also fit will into this category of 'support learning from experience'.

However, as the CSDF already contained sixteen different aspects to recognise and record during testing, extending the CSDF was considered likely to be detrimental to collecting reliable data.

The CSDF does not recognise that some aspects might more important than others or the relationships between aspects. This was appropriate at this exploratory stage of research where the aim is to recognise different aspects that might or might not be involved.

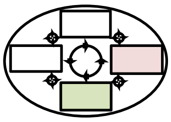
To enable the collection of reliable data, each of the aspects listed must be able to be recognised and an appropriate record made. It was recognised that some aspects require judgements to be made and would benefit from clear criteria so that these judgements can be made reliably.

Overall, the CSDF was judged to be appropriate for this exploratory research where it will be used to compare the proposed skill development theory with an example of successful practice.

3.6 Chapter 3 Summary

The purpose of the theory building stage was to develop a valid and plausible theory that can support answering of the research question identified in Chapter 2 'What happened during the L&ES to support the development of SIP skills? A new skills development theory has been constructed and justified before being translated into a conceptual framework that will support the answering of the above research question.

CHAPTER 4: THEORY TESTING AND EVALUATION

Chapter 4	Research Round 1	‘Research design and execution’ and ‘problem solving’ ES research activities 	A research design was developed to compare the CSDF with the L&ES and test two further key assumptions. An evaluation of the results concluded that SIP skills were poorly defined, students had a poorer than anticipated understanding of skills and the L&ES was most likely to be responsible the development of students SIP skills.

These two ES research activities complete Research Round 1.

4.1 Research Design

Van de Ven describes two commonly used social science research designs, variance and process (Van de Ven, 2007), where ‘What causes what’ questions require a variance design and ‘how’ questions require a process design. A variance design was selected to answer the ‘what’ orientated research question in this study. A number of factors influence the research design and are discussed in turn below.

By comparing the CSDF with the L&ES, those skill development activities in the CSDF should be recognised. However, identifying activities not in the CSDF could be challenging as when observing through one view point it can be difficult to spot items that you are not looking for. To counter this, applying ES methodology, other view-points are used (Van de Ven, 2007) and with the academics’ views already taken into account the student perspective should be sought. This was considered best captured across the whole cohort to understand the range of views and enable a deeper grounding of the problem for the researcher.

The students leave Cambridge to undertake their first SIP immediately following the Induction module for two weeks. As it would be best to capture any data whilst the L&ES was still fresh in their minds, the plan was to timetable this data capture at the end of the Induction Module. The advantage would be having a captive audience, but to cause minimal disruption to teaching, it must only take a short time.

The detailed design is identified below. As additional research questions are needed each will be given a number e.g. RQ1 to avoid confusion. To answer RQ1: “What happened during the L&ES to support the development of SIP skills?” a concurrent triangulation strategy (Creswell, 2009) was applied. The researcher view will be captured via the comparison with the L&ES and the student view via a second research question RQ2: “Can the students identify the activities in the Induction Module that have helped them to learn skills?" These perspectives can be compared to see if there are areas of convergence or divergence. All data will be captured over the same period of time and the comparison of different perspectives will enable triangulation.

The skill development activities during the L&ES were considered by the academic to be responsible for the majority of the students' SIP skills as previous cohorts had indicated informally that they had limited experience of solving industrial problems in practice. As no evidence was available to substantiate this claim, the assumption that students had low levels of SIP skills on starting ISMM required testing because, if this was not the case, this research would not be valid.

As identified in Chapter 2, a method of empirically testing the level of student skills was not available. An alternative strategy could involve splitting the cohort into two, have only one group take the L&ES and then compare the results. However, this would be unethical and impractical from a teaching view. Another strategy was to find a proxy that would indicate the level of student SIP skills on starting the course. Knowing that SIP skills are developed by experience or practice, prior experiences that could lead to the development of SIP skills e.g. group projects during their degree, were seen as a suitable indicator. Thus Research Question 3, RQ3 was developed: "What prior experience do the students have that may have enabled them to develop SIP skills?"

4.2 Research Methods

A mixed methods research strategy requires data collection methods to be selected on their merit (Teddlie and Tashakkori, 2010). A typology of five different research activities and associated data collection methods (Teddlie and Tashakkori, 2009) is shown in Table 15 below.

<table>
<tr><th colspan="2">Research Activity</th><th>Data Collection Method</th></tr>
<tr><td>1</td><td>Asking individuals for information</td><td>A: Interviews
B: Questionnaires
C: Attitude Scales
D: Personality questionnaires, inventories and checklists
E: Indirect self-reports: Projective techniques</td></tr>
<tr><td>2</td><td>Seeing what people do: Observational Methods</td><td>A: Participant observation
B: Non-participant observation</td></tr>
<tr><td>3</td><td colspan="2">Asking individuals about relationships with others: Sociometry (Network Analysis)</td></tr>
<tr><td>4</td><td>Using data collected or documented by others</td><td>A: Archival analysis
B: Meta-analysis</td></tr>
<tr><td>5</td><td colspan="2">Using multiple modes of data collection</td></tr>
</table>

Table 15. Activity Typology of Mixed Methods Data Collection Strategies

The three questions in this research round required multiple modes of data collection. RQ1 required a 'seeing what people do' research activity and RQ2 and RQ3, an 'asking individuals for information' research activity.

Of the two data collection options for 'seeing what people do', a non-participant observation strategy was selected as a general view rather participant perspective was required. Some challenges associated with observation strategies include; they are time consuming, the reasons for someone's behaviour may not be clear (Teddlie and Tashakkori, 2009) and good observation skills are required (Creswell, 2009).

Of the 'asking people for information' data collection strategies, options A and B, interviews or questionnaires, were the two options considered suitable. A comparison on the strengths and weaknesses of the two strategies (Teddlie and Tashakkori, 2009) led to questionnaires being selected because interviews were not practical in the time available and one of their main weaknesses, low response rates, could be overcome by administering the questionnaire in a timetabled session. However, the weakness of 'missing' data would still remain which could be partially mitigated by designing the questionnaires to be quick and easy to complete.

The data for RQ2 would need to be collected towards the end of the Induction Module but RQ3 would be best done early to reflect their start of course position before any influence by the programme or their peers. The proposed data collection activities are illustrated in Figure 15 below.

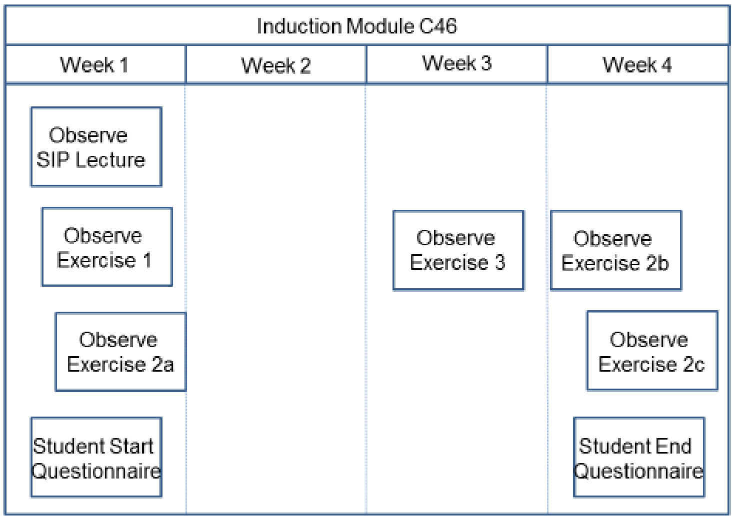


Figure 15. Data Collection during the Induction Module

The observation and questionnaire methods employed are now discussed in turn.

4.2.1 Observing the L&SE

Observations should have a minimal impact on student or facilitator behaviour (Jones, 2010, Creswell, 2009). The researcher planned to brief the class and facilitator explaining the nature of the work, how the data was to be used and then take up an unobtrusive position at the back of the teaching rooms. Such actions would also ensure compliance with ethical aspects (Creswell, 2009).

The group activities were split across a number of rooms and only 1/3 class can do Exercise 3 per day due to space and resource constraints. Whilst it was possible to observe all exercises, it was not possible to observe all groups doing all exercises. This was not seen as a major problem, as when discussed with the academic, assurance was given that similar teaching activities were applied to all groups.

The observation protocol involved one structured and one un-structured approach. The structured approach tested the CSDF where indicators were identified for each of the high level activities. In Table 16, the specific aspect to be observed was identified.

		A	B	C	D
		Skill Description	**Learning Environment**	**Experiences**	**Support Learning**
1	I	Teaching time	Summative Assessment	Number of experiences	Time for feedback
	D	Record time	Course assessment documentation	Record the number of different experiences	Record time
2	I	Generalisations and practical principles	Formative Assessment	Relevant and authentic experiences	Feedback focussed on tasks
	D	Record what was presented, how and when it happened	Record formative assessment activities	Characterise each experience in terms type and context	Record what was presented
3	I	How to do things – process steps	Explanation of importance	At a mastery level of challenge	Time for student reflection after each exercise
	D	Record what was presented, how and when it happened	Record what was said / presented	Record if any groups were able to achieve a high level outcome	Record time
4	I	Specific propositions	Level of student engagement	Facilitated to provide all with vicarious experience	Reflection outputs enable learning
	D	Record what was presented, how and when it happened	Record whether students were engaged or not engaged	Record if any examples of cohort mastery experiences were shared	Group reflection outputs

Table 16: CSDF showing structured data collection

Each cell has a different coding; I denotes Indicator, D denotes the data to be collected. The 16 different data sets included both qualitative and quantitative data. Fourteen of these would require careful recording by the observer during the L&ES and two could be undertaken at a different time i.e. B1 review of course documentation and D4 reviewing group reflection outputs.

The unstructured approach involved capturing the L&SE activities, taking regular notes on what was happening and when. This was employed to develop a better understanding of the activities involved in the L&ES and to capture data which could help to identify activities not included in the CSDF.

This amount of data to be recorded was extensive as it involved different types of data. However, its capture was considered realistic, for two reasons. Firstly, of the sixteen aspects for recording, only the skills description categories (A2, A3 and A4) and B3 might be happening concurrently, the level of student engagement was the only one that require monitoring throughout the L&ES and, B1 data did not have to be captured during the L&ES. The second reason was the researcher was a qualified HE teacher with over 10 years experience of designing, delivering and assessing practice orientated Masters level courses in addition to 14 years experience in working in a large industrial company in a variety of roles. As a result, the author was confident that the different aspects could be recognised and recorded.

4.2.2 Capturing Student Information

A two questionnaire strategy was employed, one at the start of the Induction Module 'Start Questionnaire' (see Appendix 1) to gain information relating to RQ3 and one at the end of the Module 'End Questionnaire' to collect data relating to RQ2.

Both qualitative and quantitative data required collection. The survey design recognised that language could be an issue (Teddlie and Tashakkori, 2009), as many students had English as their second language and had just arrived in the UK. Written inputs were minimised i.e. data entry required ticking boxes or circling numbers where possible, and care was taken to write clear questions and label items clearly. The questionnaires were designed taking into account good practice guidelines (Oppenheim, 1992, Jones, 2010). The author also planned to be present when the students were completing the questionnaires to answer any clarification questions.

The testing of the Questionnaire was limited – a number of iterations were undertaken with the academic, three other PhD students critiqued the survey and the final versions were reviewed and approved by the Head of Research and the ISMM Programme Director. However, there was no testing on recently graduated students who had English as a second language.

Start Questionnaire

A number of experiences were identified with the academic as those most likely to contribute to the development of SIP skills. These included three sets of activities:

- those undertaken as part of their studies e.g. group projects,
- extra-curricular University activities e.g. participating in a business plan competition and
- prior work experience.

These are shown in Table 17.

SIP skills	**Indicator 1**	**Indicator 2**	**Indicator 3**	**Indicator 4**
Solving industrial problems	Industrial placements	Participation in a business plan or design competition	Work experience	
Working as a team	Group Projects	Group based classroom exercises or simulations	Organising an event	Running a student club or society
Planning a project	Group Projects	Organising an event	Running a student club or society	
Making presentations	Individual Presentations	Group Presentations		

Table 17: Activities that may support the development of some SIP skills

To gather work experience data a tabular format was used and against a particular job, students ticked whether the role had been a full time, part time or a summer internship and entered the duration in months. See Appendix 1. A key feature of the design was to collect quantifiable data that would indicate not only what experiences students had participated in, but also to get a sense of the extent of this experience.

End Questionnaire

This sought to answer RQ2: Can the students identify the activities in the Induction Module that have helped them to learn skills? Three open questions were asked;

- What aspects of the Induction Module have been the most helpful to you in developing your skills?
- What aspects of the Induction Module have been the least helpful to you in developing your skills?
- How would you propose that the Induction Module be modified to improve skill development?

The first two questions would generate alternative data sets, the third question acts as a further indicator and as a means to gain ideas for improving practice. These three views can be compared and contrasted following data coding.

4.3 Research Execution

This section describes what happened when implementing the research design and discusses each method.

4.3.1 Observing the L&ES

All L&ES sessions were observed with the exception of Exercise 2c due to a last minute timetable change. This teaching activity followed a similar format to Exercises 2a and 2b, and whilst not ideal, it was agreed with the academic that this would have limited impact on the research. Some data was captured through studying the exercise teaching materials and by talking to the students and academic.

The author observed activities from the back of the room. During the 'experience' part of the exercises student groups were distributed over a number of rooms and the author observed those based in Seminar Room 1. Field notes were captured as the observation happened on a large A3 version of the CSDF (Table 14) with spaces for notes and then written up as soon as practical after the observation and before discussion with anyone about them, as per recommended practice (Jones, 2010). In addition, the author kept a timeline and recorded data on an excel spreadsheet at five-minute intervals on what was happening and whether students were engaged or not.

The facilitator employed a system of patrolling each group at regular intervals to assess their progress via observation and questioning them about their current activities. The observer moved position to hear the conversations when Seminar Room 1 was visited. One group, post completion of Exercises 2a and 2b, agreed that their reflection discussions could be observed. The author sat close enough to hear, but set back from the group so as not to appear a participant. Given the nature of the conversations, the observer was confident that her presence had little impact on the students!

The facilitator stated (post session) that he made sure that one or two groups achieved workable solutions in the time available and this sometimes required giving extra hints. The reason was to generate examples of success to inspire the rest of the groups.

At the end of Exercises 1, 2a, 2b and 2c, there was 30 minutes for reflection activities. Each group nominally had 15 minutes to discuss their performance and identify three aspects that had gone well and three things that could be improved. This reflection time was scheduled immediately after a whole class session where the students had presented their solutions and feedback had been given. Whilst 15 minutes was allocated, in practice it was at least 5 minutes less as students took time for a comfort break and to obtain refreshments.

When the class reconvened for Exercises 1 and 2a, 50% of teams were drawn out of a hat to share their thoughts with the class and for Exercise 2b all 8 teams were asked to present which left little time for discussion. The reflection statements made to the class were recorded by the observer.

4.3.2 Observation Method Discussion

Passive observation enabled the author to get a first-hand view and record data as it happened. The whole-class activities were easier to follow as there was just one line of action. When observing multiple groups from the back of the room it was not possible to follow what was being said. However, observing what they were doing and listening to discussions with the facilitator enabled a partial understanding of their activities.

Reflecting on the experience of observing, the author found it easy to capture field notes relating to the context and activities being undertaken but less good at recording exact words people said. Although teacher behaviour was observed – it was not possible to understand why they took particular actions. This is a weakness of observation as a method. Discussions with the facilitator post teaching session enabled some explanation.

As Exercise 2c was not observed, post exercise interviews were arranged with the same two student groups observed in Exercise 2a and 2b, and their reflective outputs were captured. In general discussions about the exercise both groups commented that they had not been as motivated for this exercise, a factor also noticed by the facilitator.

4.3.3 Capturing Student Information

The start questionnaire (Appendix 1) was undertaken in the lecture of the L&ES when 90% students registered on the programme were present and all completed the questionnaire. All students were informed about the research project before the questionnaire was administered and given written and verbal reassurance that all data would be kept confidential and used only for the purposes of research. The author was present when the survey was completed. Three students flagged that they had undertaken a five year undergraduate degree and the questionnaire only allowed for four years. They were asked to enter data for only their taught years and if all were taught to enter data for their first four years to keep the data set consistent.

29 of the 44 questionnaires were completed in full. Of the remaining 15, 8 had <5% of data points missing, 6 contained minor alignment issues between programme length and their data, and one student was unable to follow the instructions on a number of sections. The alignment issues between length of undergraduate programme came about for a number of reasons including, students taking ISMM as the final year of their undergraduate degrees and the inclusion of industrial placement years.

4.3.4 Survey Method Discussion

Two surveys were undertaken, one at the start of the Induction Module and one at the end. The response rates were very good, being 90% and 94% respectively, demonstrating that administering the survey in timetabled time was effective. As the surveys were paper-based, the data was entered manually onto the computer. Although time consuming, this did provide a feel for the data and time was saved by not having to chase on-line questionnaire returns.

The estimated completion time for the Start Questionnaire was twenty minutes and approximately 70% achieved this. From observing the class, those who appeared to require more thinking time took longer and some students, particularly those with English as a second language, may have required time to understand the question. Further testing and more careful consideration of how the data was going to be analysed would have improved the questionnaire and avoided problems with a few of the data sets such as the duration of work experience in the part-time category, where lack of data on how this compared to a full time position prevented estimations of relevant work experience.

The End Questionnaire was much shorter and the completion time was within the estimate given to the students. However some responses, and particularly to the last question “How would you propose that the Induction Module be modified to improve skill development?” were more relevant to the Module as a whole rather than specifically to skill development. Potential explanations are that: the question was not fully read, they wanted to take the opportunity to get their views across (it was the last day of the Module) or that they do not understand the process of skill development. Whatever the answer, the questionnaire design could be improved to reinforce the point that the focus was skill development.

Missing data was not a significant problem with <5% in both questionnaires. For some questions there may have not been any data e.g. work experience, for some cases it was an issue with understanding the question – some students struggled with the ethnicity question - but the majority of cases were with recalling activities whilst at University. On reflection there were too many ‘recalling activities’ type questions and the work experience section could be improved by providing a clearer explanation of what was meant and an additional question where students could give a Yes or No answer to whether they had any relevant work experience.

4.4 Results and Discussion

This research set out to answer three questions

- RQ1: “What happened during the L&ES to support the development of SIP skills?”
- RQ2: “Can the students identify the activities in the Induction Module that have helped them to learn skills?”
- RQ3: “What prior experience do the students have that may have enabled them to develop SIP skills?”

In this section, the research results and implications are discussed.

4.4.1 Observing the L&ES

To answer RQ1, the L&ES was compared to the CSDF and the results are summarised in Tables 18 and 19. Table 19 captures an example of the reflection results for Exercise 2b, and maps the statements given onto the working definition of SIP skills in Chapter 2 i.e. solving industrial problems, working as a team, planning a project and making presentations.

		A	B	C	D
		Skill Description	**Learning Environment**	**Experiences**	**Support Learning**
1	I	Teaching time	Summative assessment	Number of experiences	Time for feedback
	R	A 70 minute lecture included a 50 minute description of SIPs and some of the specific skills required. Feedback time following each exercise covered some skills in more detail, see D1R.	50% of the ISMM marks relate to SIPs. Assessment occurs after the initial development of skills	Five exercises were undertaken. Three of which took 3 hours and two lasted more than a day.	Ex 1, 2a & 2b <15 minutes per exercise. Carried out prior to the next exercise Ex 3: As part of the presentation session and prior to Ex 2b. Also time for feedback on Ex 3 reports by group and prior to SIP1.
2	I	Generalisations and practical principles	Formative Assessment	Relevant and authentic experiences	Feedback focussed on tasks
	R	The lecture covered general principles such as: common problems and their differing characteristics, the range of tools and techniques*, the general process for solving industrial problems. In post exercise feedback principles such as the need to judge the validity of information were covered. *A text book was given to each student.	Many examples were observed across a wide range of aspects involved in SIPs e.g. time management, group organisation, solution accuracy, structuring presentations, presenting data, thinking from different stakeholder perspectives.	Efficiency improvements for a packing operation. Process flow improvements for food manufacturing. Cost benefit analysis of packaging options. Factory Layout improvements for food manufacturing. Manual assembly improvements.	Ex 1 and 2a: A workable solution was presented Ex 2b: All options were discussed. The option most acceptable to the board was identified. Ex 3: Some feedback from other groups that worked on the same problem.
3	I	How to do things – process steps	Explanation of importance	At a mastery level of challenge	Time for student reflection after each exercise
	R	Defining problems was covered in the lecture and identifying the nature of the problem was discussed in the feedback sessions for Ex1, 2a and 2b. Students were	It was made explicit that problem solving skills were vital for Industrial assignments in the Lecture. This was reinforced during the exercises.	In each of exercises 1, 2a, 2b and 2c a minority of groups demonstrated mastery level. It is not known if this was achieved for Ex 3.	Nominally 15 minutes but in practice no more than 10 minutes of group reflection
4	I	Specific propositions	Level of student engagement	Facilitated to provide all with vicarious experience	Reflection outputs enable learning
	R	At least one case example was provided in the feedback sessions of Ex1, 2a and 2b.	High during the exercise tasks. Lower during presentation prep, feedback and reflection aspects.	As some groups demonstrated mastery levels this provided vicarious experiences for others.	See D4 results that follow. Some students lacked focus and interest and output capture was poor.

Table 18: Comparison of the L&ES and CSDF

The reflection outputs were colour coded using the key below.

Key	
Solving industrial problems	
Working as a team	
Planning a project	
Making presentations	

Things done well	Team	Things to improve
Assigned tasks well	A	Not well organised but better than last time
Good at timing – no mad panics		Rushed too much then had to go back and redo
Communicated well		
Assigned tasks & executed well	B	Disorganised
Good involvement		Wasted time doing the same things
Took wide perspective of issue		Presentation
Split tasks up well	C	Time Management
Communication as one person switched between sub groups		Didn't check results initially
Good answer – only missed out one calculation		Made one slide for presentation 4 times
Split into groups to analyse main options in detail	D	Made calculation error
Good teamwork and communication		Not enough checking of others work
Good professional power-point presentation		Organisation

Table 19: Reflective Outputs – example results from Exercise 2b

The results are discussed by CSDF category.

4.4.1.1 Describing skills (A)

A1 - the teaching time dedicated to describing skills was distributed between the lecture, the exercise feedback sessions and sometimes in the reflection sessions, thus there was a clear connection between A1, D1 and D4 if reflective outputs were discussed.

A2, A3 and A4 - the different aspects skill description of: practice principles, how to do things and, specific cases were all given, with some parts of A2 and A3 given in the lecture but all aspects covered during feedback sessions. Thus, there was a strong link with D2. Students were also asked to read a text book (Bicheno and Holweg, 2009) on problem solving tools and techniques.

All four aspects of A were observed. CSDF connections were identified between A1 and D1, and A2, A3 and A4 with D2.

Students appear to develop their own understanding of SIP skills from the actual experiences of doing the exercises and from observing others as well as the descriptions provided. The multiple cycles of describing and doing appear to progressively build a students' understanding of the skills which aligns with EL specifically Dewey's Model – see Figure 7. It also highlights the importance of experience – however, developing skill definitions through experience may cause inconsistent understanding, as each person's interpretation was likely to be different.

Of the SIP skills identified in the working definition in section 2.3.4 'solving industrial problems' and 'making presentations' received the most description. Only aspects of 'working as a team' and 'planning a project' critical to undertaking SIP1 were covered, such as dividing the work. Many of the student groups ran out of time in Ex 1 as they had primarily worked together. This enabled the academic to demonstrate why such skills were important in a SIP context (B3). Thus A was connected to B3.

The description presented in the lecture came with slides and references so students had something to refer to. The description during feedback sessions was not recorded in a formal way, so unless students remembered or took notes, aspects of skill description could be forgotten. Through the feedback sessions students were able to develop an appreciation of what a "good" performance looked like for the problem solving and presentation aspects. However, this aspect of describing skills was largely missed. If students understood the expected SIP performance levels they could evaluate where they think they are, determine what to improve and set themselves progression targets.

Overall, the amount of description is light in comparison with the range of different skills required in a SIP. The lack of definition of skills will be a contributing factor but the multiple experiences provided do appear to off-set this.

4.4.1.2 Create a learning environment to encourage deep learning (B)

B1 and B2: The timing of skills assessment, with formative in the L&ES and summative post L&ES with each SIP, was found to be appropriate to encourage a deep learning approach and appears to be aligned with literature (Knight and Yorke, 2006). The summative assessment, known to be problematic see 2.3.3, might limit deep learning post SIP1 but should not impact on the L&ES.

Formative assessment (B2) took multiple forms including: model answers, comments on the solutions presented, and guidance on how to improve specific aspects of practice. These were judged to support skill development but a weakness was the lack of capture of this feedback as mentioned previously. Formative assessment (B2) involved providing feedback (D1 & D2) which connects these aspects of the CSDF.

Explanations of why some SIP skills were important (B3) happened during the lecture, pre-exercise, and in the feedback sessions where examples of good and bad practice were used to highlight the benefits of doing something well. Industrial problem solving tasks that were essential to completing a SIP on time e.g. divide the work and arrange access to data, were particularly emphasised. Concerns about capturing this knowledge raised previously also applies here.

Different levels of student engagement (B4) were observed. Levels were high during the active parts of the exercises, with some exceptions observed in the larger groups used in Exercise 2. Levels of engagement fell during the passive aspects of the group presentations, feedback and reflection activities. Tiredness on completion of an intense activity could also be a factor due to a lack of breaks.

All four aspects of B, ‘Creating a learning environment’, were observed and connections were identified between Formative Assessment (B2) and Feedback (D1, D2) as well as Explanations of skill importance (B3) and Describing skills (A2, A3, A4).

Most formative assessment appeared to be relevant to the context and based on the experience of the academic but with a significant proportion being ad-hoc and without reference to detailed skill definitions or performance level indicators, there are concerns that some areas were missed.

Deep learning requires students to engage in learning activities that span the full range of cognitive levels from memorise to reflect (Biggs and Tang, 2007). The L&ES contained activities that spanned this range, but students were asked to do some higher order activities e.g. reflect, when tired, and with insufficient time or guidance.

When observing student engagement, it was possible to see what they were doing and hear what they were saying in a whole class situation, but not what they were thinking or saying when working in small groups. Therefore, only a partial evaluation of engagement levels was possible. Levels of physical activity were higher in the group tasks and lower in the whole class feedback and reflection activities reflecting the active and passive nature of the activities. Some individuals were not as engaged as others in the larger group Exercises 2a, 2b and 2c. Potential causes are uneven work distributions and lack of individual motivation. Ways to increase engagement could include the introduction of group observer roles and a reduction in team numbers.

4.4.1.3 Experiences (C)

The five exercises (C1) appeared effective in demonstrating different industrial problems. Previous students had developed Exercises 2a, 2b and 2c to provide some additional experiences.

The experiences provided (C2) were relevant and representative of industrial problems. There were authenticity issues that caused some students to question relevance as the industrial situations simulated appeared outdated e.g. communication by memo rather than email. The exercise resources provided the situational knowledge (Eraut, 1994) associated with the problem and simulated different types of information, featuring incomplete and conflicting data, consistent with many SIP situations.

Mastery level experiences (C3) appeared to be achieved in four of the five exercises as at least one team successfully solved the problem by presenting a justified workable solution, as judged by the academic. It was not possible to determine whether Mastery experiences were achieved for Exercise 3, as there were multiple groups, tutors and session times involved. The academic testified that some groups achieve Mastery experiences without assistance thus indicating that the level of was appropriate. However, this could not be evaluated by the researcher.

In terms of facilitation (C4), it was not known if the students recognised any hints that helped them to achieve a 'Mastery' experience. For these experiences to generate self-efficacy then the group should believe that they have achieved it themselves. This requires high levels of facilitation skills by the teacher. As 'Mastery' experiences were generated for some teams and the others witnessed their achievement by watching their presentations and hearing their feedback, then 'Vicarious' experiences were generated for the rest of the class.

All four aspects of C – providing multiple experiences relevant to practice – were observed. An improvement to the CSDF would be to rename the category as 'providing multiple practice experiences' and separating out the relevant and authentic aspects in C2.

Complete resource 'packs' were available for each group of students for all five exercises demonstrating the careful preparation by the academic. This was an important part of ensuring the exercises run smoothly and was not explicitly included in the CSDF.

Providing multiple experiences relevant to practice was identified as the most important strand of the CSDF for developing skills – partly because the learning associated by doing them could be seen to compensate for the lack of skills description and what appeared to be poor learning from reflection.

Whilst the range of exercises provided five different industrial problems and five opportunities for presentations, there were only three different team and project planning situations as the groups and format stayed the same for all three parts of Exercise 2. So there is scope to modify Exercise 2 to extend the learning opportunities.

4.4.1.4 Supporting Learning from experience (D)

Specific time for feedback (D1) was built into the timetable and in all cases promptly and prior to the next exercise or SIP1. This time appeared short given the complexity of the exercises and the key role that formative feedback plays in developing skills, in particular - workable solutions were presented quickly. With the exception of Ex3, where there are opportunities for group feedback on their presentations and reports, all feedback was undertaken in a whole class setting.

The feedback provided was focussed on (D2) the problems being solved and on how performance could be improved but, with the exception of the worked examples for Ex 1 and 2a, did not appear to happen in a systematic way. If a general learning point arose during presentation feedback, the opportunity was usually taken to discuss this with the class but there was an over reliance on students remembering what was said. Opportunities to provide formative feedback were missed e.g. individual feedback on presentation skills where a 'one good point and one for improvement' approach could have been helpful for both the individual and the class. There was some evidence to suggest that feedback and its importance may not be fully understood as the level of student engagement fell during feedback activities and only a few were actively taking notes. Whilst there may be alternative reasons, such as tiredness, this may indicate that the role of feedback in developing skills was not fully appreciated by the students.

There was time for student reflection (D3) between exercises both as a group and individually – but only group reflection time was scheduled (except for Ex3). Reflection happened immediately after exercise feedback for Ex. 2a, 2b and 2c when students were likely to be tired and had had no time for individual reflection. Overall time for group reflection was limited and it was not known whether students took any individual time to reflect.

The reflection activity (D4) required the students, as a group, to identify three things that went well, three things that did not go so well and be prepared to present these back to the class. Example results are shown in Table 19. The strengths of the method include the provision of a balanced perspective, it was simple to understand, and there was an incentive for the exercise to be undertaken seriously. However, the reflective outputs shared with the class were superficial and general in nature e.g. time management, and contained contradicting statements e.g. 'good at timing' and 'rushed too much then had to go back and redo'. These results suggest that the reflective activity was too short and did not encourage a focussed or in depth consideration of the issues. The outputs did enable the facilitator to identify some common issues that prompted feedback and discussion on practice options that could lead to better outcomes.

An examination of the group reflective outputs concluded that they remained superficial throughout the series of exercises. Three potential reasons are suggested. Firstly, there was no encouragement for students to increase the depth or their approach to reflection so students may have assumed this level of reflection was appropriate. Secondly, students were not taught reflective skills or given reasons why they were important. Thirdly, the majority of the reflections concerned project management or team working aspects and as students were given limited descriptions of these skills they had little to reflect on.

It was interesting that multiple experiences had no noticeable impact on the development of the students' reflective outputs. Whilst this may reflect the limited effectiveness of the reflection activity, it indicates that skill development requires multiple coordinated aspects to be successful.

All four aspects included in D – supporting learning from experience – were observed. This category could be expanded to include aspects such as conversion of feedback and reflective outputs into action plans for the next exercise or SIP as per ELT (Kolb, 1984, Moon, 2004).

The facilitator, or facilitators in the case of Exercise 1, spent little time observing the groups appearing to use their experience of the exercises and the reflective outputs of the students as a basis for feedback. Whilst this approach was efficient in terms of facilitator time, it could be preventing formative feedback opportunities.

Opportunities to increase formative feedback in the L&SE should be investigated. This could involve additional tutors and involving students with suitable guidance. Getting students to evaluate others and then provide feedback will also support their learning of skills (Race, 2010, Biggs and Tang, 2007).

4.4.1.5 Overall

All sixteen indicators in the CSDF were recognised during the L&ES. In addition, the following were also recognised as contributing to skill development:

- the provision of a suitable physical learning environment e.g. sufficient and flexible space for facilitated group activities. Suitable teaching spaces are available IfM where the building is recent (2009).
- provision of all resources required to support the experiences

This provides an answer to RQ1: “What happened during the L&ES to support the development of SIP skills?”

The L&ES could be improved by:

- creating a formative feedback culture, where expectations and multiple mechanisms are established for formative feedback
- maintaining the L&ES as a safe learning environment where students can fail as well as succeed in their pursuit of learning.
- introducing activities that convert feedback and refection into development action plans to complete the EL cycle.

The CSDF enabled some preliminary testing of the Skills Development Theory (SDT). The many connections between the different aspects of the CSDF reinforce the view that skill development is an interlinked system and a systems model view is an appropriate way to represent this. This suggests that the further development of the model proposed (Figure 14) would be appropriate.

Of the four categories in the CSDF, A – Describing Skills, was the most difficult to deploy as the different aspects of skill description: practice principles, how to do things and, specific cases (A2, A3 and A4), were sometimes difficult to distinguish. This was not unexpected given the under-conceptualised nature of the field (Young and Muller, 2014). It was noticed that the description and understanding of skills built through the multiple exercises.

Of the four categories, the provision of the multiple experiences C and supporting learning from them D, were seen to be directly responsible for developing skills, with categories A and B providing essential enablers.

The elements of the CSDF are different in nature. Some are important for design e.g. C2 'experiences that are relevant and authentic', others relate to good delivery practice e.g. D1 'time allocated to provide prompt feedback' and others are more evaluative in nature e.g. B4 'level of student engagement'. Separating these different views would enable a process view of the teaching perspective to be generated.

Further work is required to investigate the typical number of different exercises required to become sufficiently proficient for different skills. This will depend on many factors: the range of representative problems to be experienced prior to real-world practice, the diversity of contexts in which they happen, the complexity of the work involved, the level of resource available and the abilities of the students.

Determining whether an experience is set at a mastery level of challenge will in practice take time as the experience would have to be run several times and adjustments may be required. This is a key aspect of developing self-efficacy, recognised as a foundation aspect of graduate employability (Knight and Yorke, 2002) thus the return on investment in teacher time should provide a good return for the students.

Some aspects of the proposed SDT such as the climate/ethos of the course were not tested as this would have required more extensive observation of the Induction Module as a whole so these aspects still require testing. The SDT remains promising after this first test but requires much more extensive testing.

4.4.2 Survey Research

Surveys were undertaken to answer RQ2 and RQ3. The results are presented in three parts: the profile of the respondents, the recognition of skill development activities (RQ2) and SIP related activities undertaken prior to the programme (RQ3).

4.4.2.1 Profile of the Cohort

The profile of the C46 students who completed the survey, in terms of sex, length of undergraduate programme, age and nationality was collated to check whether this cohort was typical.

Sex: Male 70% Female 30%

Undergraduate degree programme length: 3 years: 34%, 4 years: 55%, 5 years: 11%

Age profile: See Figure 16

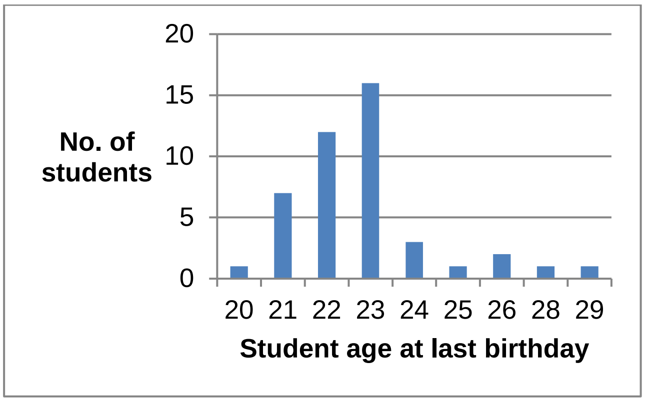


Figure 16. Age profile of C46

Nationality: There were 20 different Nationalities, with three highest being French 23%, German 16% and Chinese 14%. The distribution by region is shown in Figure 17.

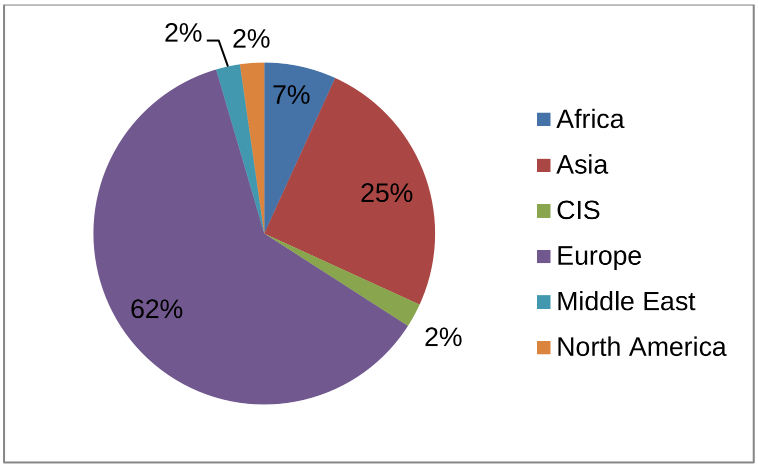


Figure 17. Regional distribution of C46 nationalities.

This profile was confirmed as being typical of most cohorts with one exception, C46 had 49 students which was higher than the target range of 40 to 42.

4.4.2.2 Recognition of skill development activities

The data to answer RQ2 was collected in the 'End questionnaire'. This was administered on the final day of the Induction Module at the end of a taught session and the three questions set out in section 4.2.2 were asked. 94% of students completed these questions. Each question is addressed in turn.

What aspects of the Induction Module have been the most helpful to you in developing your skills?

125 reasons were given, ranging from 1 to 9 per student, with an average of 2.7. The raw data was analysed by coding the results using a grounded theory approach. Eight broad categories emerged from the data. 'Learning facilitators' was a category that includes aspects such as practice, feedback, observing others, real life examples, practical approach to lectures and being able to ask questions.

Category	Aspects of Induction Module **most** helpful in developing your skills	% student responses	Aspects considered to develop skills by researchers
A	Industrial Visits	12.9%	12.9%
B	L&ES Exercises	22.6%	22.6%
C	Team Working	13.7%	13.7%
D	Making Presentations	16.1%	16.1%
E	Subject Lectures	9.7%	
F	Skills Lectures	11.3%	11.3%
G	Learning Facilitators	8.9%	8.9%
H	Other	4.8%	
		100.0%	85.5%

Table 20. Aspects of Induction Module that students thought most helpful in support of skill development

The 'other' category contained reasons that could not be placed and were not considered supportive of skill development. The data categories and data coding were agreed with the academic and the results are shown in Table 20.

Categories B, C & D associate directly with the development of SIP skills due to their focus and practical nature. Industrial visits have a dual purpose – to develop knowledge of Manufacturing Industry and develop skills related to observing and evaluating factory operations. It was not known if the dual purpose was understood by the students.

The results indicate that the students and the researcher agreed on 85.5% and so disagreed on the remaining 14.5% of these activities.

What aspects of the Induction Module have been the least helpful to you in developing your skills?

61 reasons were given, ranging from 0 to 5 per student with an average of 1.4. The raw data was analysed using the same eight broad categories as above. All the reasons given fitted into these eight categories with the exception of the 'lecture' responses as these covered both categories E and F. See Table 21.

Category	Aspects of the Induction Module **least** helpful in developing your skills	% student responses	% responses that demonstrate an understanding of skills development	% responses demonstrating limited of understanding of skills development
A	Industrial Visits	16.4%	6.6%	9.8%
B	IPS Exercises	9.8%	4.9%	4.9%
C	Team Working	4.9%	0%	4.9%
D	Making Presentations	1.6%	0%	1.6%
E	Subject Lectures	11.5%	11.5%	0%
E&F	Lectures	49.2%	49.2%	0%
F	Skills Lectures	1.6%	0%	1.6%
G	Learning Facilitators	3.3%	3.3%	0%
H	Other	1.6%	0%	1.6%
		100%	76%	24%

Table 21. Aspects of Induction Module that students thought least helpful with skill development

The results in Table 21 indicate that the students and the researcher agreed on 76% and thus disagreed on 24% of activities.

How would you propose that the Induction Module be modified to improve skill development?

71 reasons were given ranging from 0 to 7 per student with an average of 1.54. The raw data was analysed using the nine broad categories that had emerged from the previous data set. All reasons given fitted into these nine categories.

The results shown in Table 22 indicate that the students and the researcher agreed on 63.5% and therefore disagreed on 36.5% of activities. The disagreement could be reduced to 14.1% if all the suggestions regarding Lectures (E&F) were linked specifically to skills lectures. This was considered unlikely as many suggested improvements were of a general nature e.g. lectures should have clear learning outcomes.

Category	Aspects of Induction Module to be improved in support of skills development	% student responses	Aspects considered to develop skills by researchers
A	Industrial Visits	11.3%	11.3%
B	IPS Exercises	12.7%	12.7%
C	Team Working	1.4%	1.4%
D	Making Presentations	9.9%	9.9%
E	Subject Lectures	4.2%	
E&F	Lectures	22.4%	
F	Skills Lectures	8.5%	8.5%
G	Learning Facilitators	19.7%	19.7%
H	Other	9.9%	
		100.0%	63.5%

Table 22. Aspects of Induction Module that students thought most importance to improve related to skills development.

Over the three sets of responses it was shown that there was a varying level of agreement between the students and researchers on the activities that support skill development. This could indicate that there was a variable level of understanding of skills and their development by the students.

4.4.2.3 SIP skills related development activities prior to ISMM

The data collected in the start questionnaire was designed to give an indication of the level of prior experience the students had that might relate to SIP skills. Three groups of data were collected: activities undertaken during their HE course, extra-curricular activities at University and work experience. These are presented in turn. It was estimated whether these prior skill development opportunities had the potential to generate skills at a level equivalent of the L&ES. These levels were discussed and agreed with the academic and are categorised in the results below as significant.

A: Activities undertaken during course

There were five different activities in this category – see Table 23. 43 data sets were captured where students indicated how often they did these activities in each academic year by selecting one of the following categories: never, once or twice, three to ten times or over 10 times.

There was a concern that the activity descriptions might not be interpreted consistently as the questionnaire had not been tested on recent graduates. As there were students who had taken the same degree programme at the same time, the data from these groups was analysed to identify any significant variances, as this would be an indicator of inconsistent interpretation. A high level of correlation was expected between group members but it was recognised that there might be some minor differences due to elective choice etc. The results are in Table 23 and underneath are the agreement level descriptors.

	Case 1: Superlec 3 Electrical Eng. students	**Case 2: Glasgow** 2 Product Design Eng. students
Activity during course	**Agreement Level**	**Agreement Level**
Group Projects	Full	Full
Individual Presentations	Full	Full
Group Presentations	Good	Good
Industrial Placements i.e. time spent working in a company	Good	Full
Group based classroom exercises or simulations	Poor	Poor

Table 23. Comparison of Student Data

Agreement level descriptors:

- Full – same activity per year rates
- Good – activity per year rates in adjacent similar categories
- Poor – contradictory activity per year data

The results indicate that 'group based classroom exercises' was not recognised consistently by either group of students, so that data set was discounted. The remaining four data sets were analysed and the results are summarised in Table 24.

Activities undertaken as part of their University degree	No. of students with experience	No. of students with 'significant' experience i.e. more than 10/year in at least one of their last two years of study	Average number per student per year of study (minimum)			
			Year 1	Year 2	Year 3	Year 4
Group Projects	100%	9.3%	1.6	1.9	2.9	3.4
Individual Presentations	98%	9.3%	0.8	1.1	2.2	3.0
Group Presentations	98%	9.3%	1.0	1.3	2.3	3.2
Industrial Placements	67%	2.3%	0.3	0.6	0.9	0.9

Table 24. Activities undertaken as part of University studies

As the four activities were only described briefly, wide interpretation was likely, particularly with an International cohort in their first week of study, so only a high level of analysis was undertaken. The analysis indicated that the number of activities increased as students progressed through their course, with 67% of students having experienced all four aspects. Of the four activities, Industrial Placements was the only one were a large proportion (33%) had no experience. A small minority of students indicated that they had 'significant' experience. As the nature of the experiences are not known and some might have been minor or repeated activities it was not possible to gauge what this means – however it was an indication that only a small minority (around 10%) of the students might already have the SIP skill levels required.

B Extra–curricular activities at University

The three extra-curricular activities investigated were: 'participating in a business plan or design competition', 'organising an event e.g. a student ball' and 'running student club or society'.

43 sets of student data were captured where students indicated how often they did these activities in each academic year by selecting one of six categories: never, once or twice a year, once or twice a month, once or twice a week, once or twice a day or 'a significant effort over a short period of time'. As in the previous section, only a high level analysis was undertaken, as there could be a wide interpretation of these briefly described activities.

	No. of students who had done these activities	No. of students who never did these activities	No. of students who had 'significant' experience of these activities
Business Plan or Design Competition	56%	44%	7% – seriously involved in 2 competitions
Organising an event – e.g. student ball	88%	12%	19% – minimum of once or twice a week and over at least 2 years of study
Running a Student Club or Society	60%	40%	21% – minimum of once or twice a week and over at least 2 years of study

Table 25: Extra-curricular activities at University

Although the average number of experiences per year could not be calculated from this data set, from the raw data, it was determined that involvement in such activities increased as students progressed through their studies. From the results presented in Table 25 it can be seen that whilst more than half had been involved in each of these activities, only a small proportion (21% or less) were likely to have 'significant' experience of doing these which fell to 7% in the case of Business Plan competitions.

<u>C - Prior work experience</u>

44 sets of data were analysed. The data were consistent in manner indicating that the question had been understood. The only exceptions were one student who provided company names rather than job titles and a two had entered data related to academic work e.g. writing a dissertation. Two students did not provide any data so it was assumed that they had no work experience.

The objective was to obtain an indication of prior work experience in industrial or business roles – i.e. experience that might help them undertake a SIP. The data was sorted by roles, any not related e.g. tutoring, was removed. Part-time roles were also not considered as

- there was insufficient data to assess how long students had spent in these roles on a full time equivalent basis and
- most part-time jobs did not overlap with SIP related activities or contexts.

89 data sets were analysed. For the six instances when a job duration was given in halves of months, it was rounded up to nearest whole number. Two aspects of the results are presented; how many different industrial / business jobs had the students undertaken prior to the ISMM in Figure 18 and, the duration of these jobs in Figure 19.

Number of jobs or internships held by students prior to ISMM

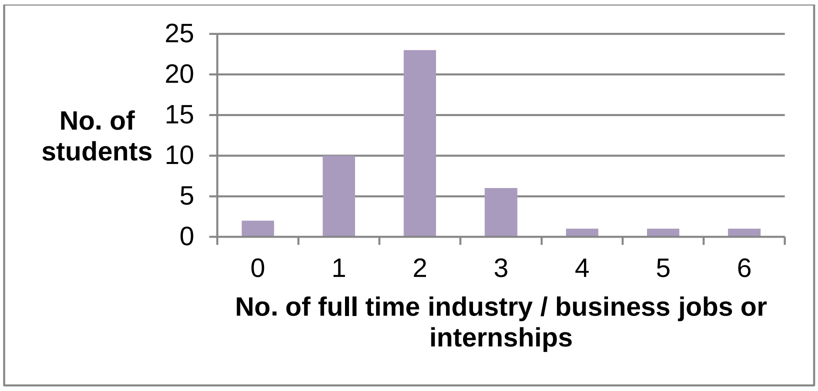


Figure 18. No. of industry or business jobs/internships by student.

For this data set the mean, mode and median values were all 2.

Amount of work experience prior to ISMM (months)

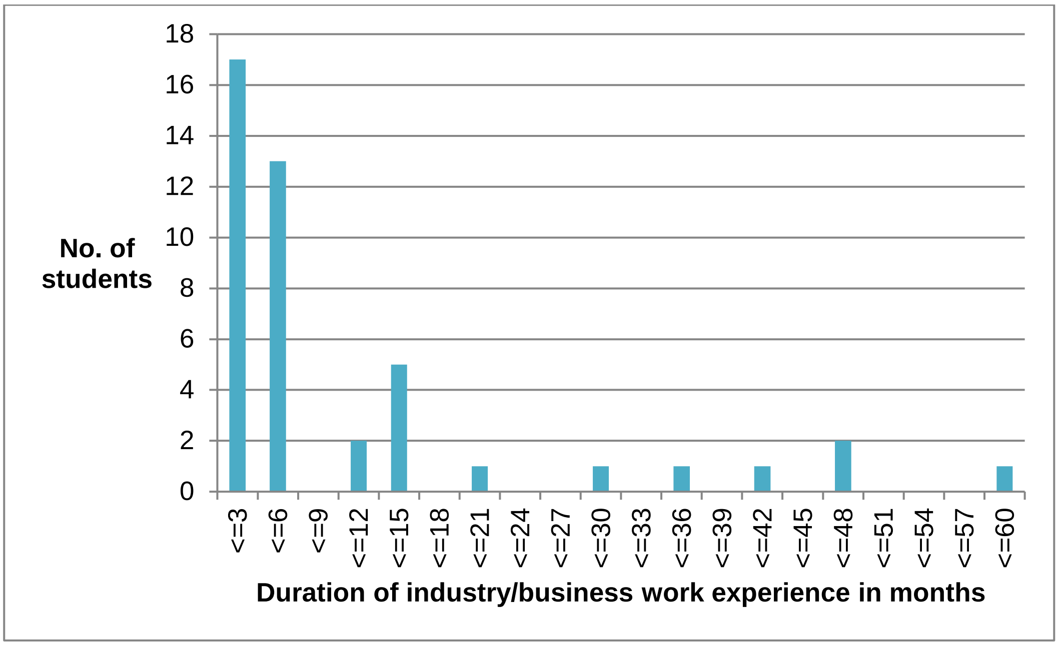


Figure 19: Total amount of prior work experience by student

For this data, the mean was 10.6 months, the mode 3 months and the median 4 months. The duration of work experience varied significantly between students. A check was made to test the accuracy of the data by comparing their date of graduation and age at last birthday and no inconsistencies were found.

The distribution of the data shown in the Figure 19 revealed that 39% have between 0 and 3 months' work experience, 29% between 4 and 6 months experience and the remaining 32% have between 10 and 60 months experience. In this last category

11.4% have greater than 3 years which when combined with different roles could be a significant help when undertaking SIPs.

4.4.2.4 Results

In answer to RQ2, “Can students identify the activities in the Induction Module that have helped them to learn skills?” the results described in 4.4.2.2 would suggest that this is variable and it was lower than expected.

It was expected that the students would have a better understanding of skills and how they are developed from their previous life experiences. Whilst there may be other contributing factors to these variable results such as the questionnaires themselves, previously discussed, there was sufficient evidence to suggest that skills and/or skill development was not fully or consistently understood. This should be investigated further and indicates that the student factors of ability and prior knowledge, eliminated from the SDT in Chapter 3 requires reconsideration.

To answer RQ3, “What prior experience do the students have that relates to developing SIP skills?” the multiple sets of results are collated and presented below against the framework shown in Table 26.

SIP skills	**Indicator 1**	**Indicator 2**	**Indicator 3**
Solving industrial problems	Industrial placements	Business plan competition	Work experience
% with no / some experience	33% / 67%	44% / 56%	4.5% / 95.4%
% with significant experience (subset of ‘some’ above)	2.3% More than 10/year in at least one of their last two years of study	7% - Significant effort in two competitions	11.4% >=3 years 7% >3 roles
Working as a team or **Planning a project**	Group Projects	Organising an event	Running a student club
% with no /some experience	0% / 100%	12% / 88%	40% / 60%
% with significant experience (subset of ‘some’ above)	9.3% More than 10/year in at least one of their last two years of study	18.6% Significant involvement in at least 2 years of study	21% Significant involvement in at least 2 years of study
Making presentations	Individual Presentations	Group Presentations	
% with no / some experience	2.3% / 97.7%	2.3% / 97.7%	
% with significant experience (subset of ‘some’ above) More than 10/year in at least one of their last two years of study	9.30%	9.30%	

Table 26: Summary of student prior experience data

As both ‘planning a project’ and ‘working as a team’ have the same set of indicators they are combined on one row.

These results are particular to this cohort due to the small size of the student population. However, this cohort was considered representative of recent cohorts and the data should be sufficient to indicate whether assumptions made related to this research are likely to be valid or require further testing.

Solving industrial problems was the weakest area of experience and where the indicators are less likely to be reliable. Of the three indicators doing a business plan or design competition was probably the closest match with ‘solving industrial problems’ as the students will have actually been involved in solving an ill-structured problem in an unfamiliar context. Industrial placements or work experience were likely to be of a general nature where students get to observe a new environment and apply their existing skills in a new context. Only 7% students were considered as potentially having ‘significant’ experience of business plan or design competitions i.e. heavily involved in two different competitions. Not knowing the level of challenge in these competitions this level of experience was likely to be overstated rather than understated.

All students had undertaken group projects as part of their courses so they all had experiences which should have helped them develop some ‘working as a team’ and ‘planning a project’ skills. Such skills may have been further developed in those who took part in ‘organising an event’ and ‘running a student club’. How transferable these might be to a SIP context is not possible to say, but working as a team whilst organising an event where there is a hard deadline would simulate some aspects of a SIP. It is possible that around 20% of the students in the cohort could already have the level skills that the L&ES might generate. This is still only a small minority of the cohort.

Only one student had not made a presentation, so most had prior experience to draw on when developing skills. Not knowing the type and context of the presentations it is impossible to say how closely they resembled SIP presentations. Around 10% of students had the level of experience, considered equivalent to that in the L&ES.

In answer to RQ3, there was sufficient evidence that the majority of students at the start of the programme had low levels of SIP skills, thus indicating that the L&ES was largely responsible for developing these skills. The students were likely to be weakest on the industrial problem solving skills so the teaching focus on this aspect in the L&ES was appropriate.

4.5 Problem Solving

Having answered the questions – the final research activity for Research Round 1, problem solving, is undertaken.

Problem solving, in the ES methodology, involves communicating and interpreting the findings with the intended audience (Van de Ven, 2007). At the end of this exploratory research stage, Research Round 1, the intended audience was the L&ES academic and the outcome of this activity was to determine the focus of Research Round 2 based on the criteria of impact (Van de Ven, 2007). As the L&ES academic was involved in the research, in practice this activity overlapped with the previous research activity and the results reported and discussed in sections 4.4 have been communicated and agreed. The main conclusions are presented below with the rationale on what should be the focus of Research Round 2.

4.5.1 Main Research Round 1 Conclusions

The development of SIP skills was found to be a complex process with many different aspects. The many connections identified between the different aspects of the CSDF reinforce the view that that skill development is a complex, interlinked system and a systems model view is an appropriate way to represent this.

All sixteen aspects of the CSDF were found to be present in the L&ES, two additional aspects were observed and a further three suggested. The weakest aspects of the skills development process were the lack of description of SIP skills and the reflection activities.

The proposed Skills Development Theory (SDT) is promising but more work is required to test aspects not included in the CSDF and to a develop an alternative approach for describing skills that can also be used for assessment purposes.

It was concluded that across the cohort there was a variable understanding of skills and their development which was lower than anticipated indicating that 'student factors' previously eliminated from the SDT should be considered for reinstatement.

From the investigation of student prior it was concluded that the level of SIP skills on starting the programme was likely to be low and thus the L&ES was the main contributor to the development of their SIP skills.

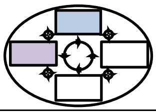
4.5.2 Focus for Research Round 2

Considering the above, along with the problem diagnosis in Section 2.5, it is the lack of definition and description of SIP skills that remains a significant problem, which if solved, would generate the biggest impact in terms of research and practice because:

- definition and description is required to develop ILO's and the associated assessment criteria to support teaching and learning
- the CSDF lacks clearly distinguishable aspects of skill description
- testing of the SDT in relation to SIP skills cannot be undertaken unless reliable assessment mechanisms are in place

So describing SIP skills will the focus of Research Round 2.

CHAPTER 5: DESCRIBING SIP SKILLS

Chapter 5	Research Round 2	Problem Formulation and Theory Building ES research activities 	An analysis of the skills description problem identified in Chapter 4 was undertaken from both practice and academic perspectives. A research question identified and a conceptual SIP framework was constructed from literature.

This is the start of Research Round 2.

5.1 Problem Formulation

The four sub-activities associated with Problem Formulation: situating, grounding, diagnosing and resolving the problem (Van de Ven, 2007), are considered in turn.

5.1.1 Situating the problem

A description of SIP skills is required to facilitate a common understanding between teachers and students and to assist teachers in developing ILO's and assessment methods. This description would also benefit from being aligned with terminology in the workplace as this is where students will undertake SIPs.

The research is to be undertaken over one academic year with testing in the period from October to March for ISMM C47 when students do their four SIPs.

5.1.2 Grounding and diagnosing the problem

Grounding the problem has three aspects: establishing that the problem is an instance of a pervasive problem, the collection of data to diagnose the problem in terms of practice, the identification of relevant academic models and theories to diagnose the problem in terms of theory. Grounding and diagnosing will be combined for both the practice and theory perspective. This enables a progressive and iterative process to be applied until a full diagnosis of the problem is achieved.

5.1.2.1 Pervasive Problem

Subject Benchmark Statements e.g. Engineering (QAA, 2015) provide a picture of what graduates might reasonably be expected to know, do and understand at the end of their degree. The 'do' aspect is associated with the skills that students should be able to demonstrate. Individual HE Programmes capture this information in a Programme Specification Document. So being able to describe skills is a pervasive issue in HE. At the programme level, these are typically high level statements and, from personal experience in a number of HEIs, are similar to those stated in section 2.1.2 used in the ISMM programme. These descriptions require further expansion to enable appropriate teaching and assessment.

5.1.2.2 Grounding and diagnosing the problem - practice perspective

The practice view was established through discussions with SIP tutors, and in particular the L&ES academic, because they hold the expertise to run SIPs and little was captured in a formal way as every SIP is different.

The initial description of SIPs to students, comprises six sequential stages: data gathering, analysis, problem definition, generate solution, implementation and reporting. It was presented in the lecture of the L&ES as shown in Figure 20. Of the six stages, implementation was the one stage that rarely happens in practice due to the short timescales of a SIP. In comparison with the working definition of SIP skills in section 2.3.4 this covers ‘solving industrial problems’ and ‘making presentations’ but not ‘managing a project’ or ‘working with others’.

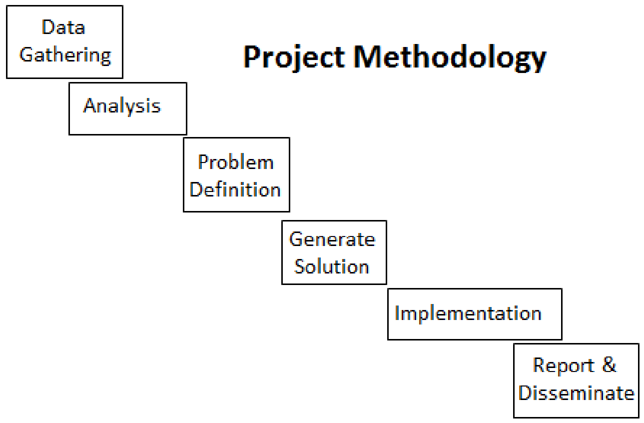


Figure 20: SIP Methodology as presented to C47 students

A comparison of the SIP methodology (Figure 20) with the skills in the programme specification described in Table 11 was undertaken Table 27 below. Here ✓✓ denotes a direct association and ✓ denotes a partial association.

This shows that skills 2, 3 and 5 have only partial links with the SIP Methodology, there are no links with implementation stage, and it was not clear where ‘Determine appropriate methodology for problem solving’ fits. This analysis further demonstrates the lack of clear and consistent definition of industrial problem solving skills and that skills are described at a high level.

No.	Stages in the SIP Methodology / Skills in Programme Specification	Data Gathering	Analysis	Problem Definition	Generate Solution	Implementation	Report & Disseminate
1	Undertake problem identification and definition	✓		✓✓			
2	Research appropriate background information and theories	✓					
3	Determine appropriate methodology for problem solution		✓?		✓?		
4	Identify, gather, analyse and evaluate appropriate data	✓✓	✓✓				
5	Prepare a business and finance case to justify a recommendation				✓		
6	Communicate effectively (in writing, verbally and graphically)						✓✓
7	Presentations						✓✓
8	Written reports						✓✓
9	Project management						
10	Working with others						

Table 27: Comparison of Project Specification Skills with the SIP Methodology.

After the L&ES, students are still novices at solving industrial problems in a company context. SIPs are a tough challenge, attempting to deliver real value, to a host company, within two weeks. When a company first becomes aware of SIPs, they are usually sceptical about what might be achieved. Students are encouraged to use an approach found to be successful in practice i.e. develop hypotheses related to the potential causes of the problem, then take a data driven approach to prove or disprove the hypotheses and iterate as required. This enables a logical analysis of the problem and minimises the need for experience - ideal for numerate but novice graduates.

So grounding and diagnosing the practice perspective has determined that

- There is a ‘process’ involved in solving the industrial problems supported by a set of ‘through-SIP’ tasks related to the generic aspects of managing a project and working with others
- the ‘implementation’ stage of the process rarely happens
- the current descriptions of SIPs are high level, inconsistent and incomplete

- a data driven, hypothesis approach was a successful strategy that enables novice students to apply their analysis skills to unfamiliar problems and contexts and develop valuable insights for companies

5.1.2.3 Grounding and diagnosing the problem - Academic Perspective

The objective of this section is to identify academic models and theories that relate to the problem, and then apply them to develop a diagnosis from an academic perspective. As discussed in section 2.4.1 defining skills is problematic because skills are context specific. To define skills one must know both the activity and the context. As the context always varies, this would suggest that an activity approach was the way forward because it is a necessary step in defining skills.

This aligns with the task approach used in Australia (Dowling and Hadgraft, 2012), described in section 2.4.4, found to be successful in describing tasks undertaken by early-career graduate environmental engineers (Dowling and Hadgraft, 2013) because the task descriptions could be reliably understood by both academics and employers. The result was a Graduate Capability Framework (**GCF**) for Environmental Engineering Degree Programs (Dowling and Hadgraft, 2013).

Dowling and Hadgraft applied the principles of job and work analysis (Brannick et al., 2007) where ‘job or work’ analysis is defined as “the systematic process of discovery of the nature of a job by dividing it into smaller units, where the process results in one or more written products with the goal of describing what is done…” (Brannick et al., 2007). Brannick et al. recognised that work analysis terms, such as ‘task’, mean different things to different people so they defined a scheme to clarify their definitions. A subset of these definitions is shown in Table 26 along with an example from a typical job. They note that it was important to get the information to serve the purpose for which it is needed, rather than be overly focussed on the terms, number of, or distinctions between levels.

It can be seen from the additional explanation in Table 28 that accompanied their activity definition (Brannick et al., 2007) that there can be a significant difference between a typical job and a complex job. Whilst no ratio was given, it was implied that that this might be in the order of at least three from their use of the word several. There are 392 tasks listed in the GCF indicating that graduate engineering jobs are more likely to be ‘complex’ than ‘typical’.

Term	Definition	Additional Explanation	Example (Typical Job assumed)
Job	A collection of related positions that are all similar enough in terms of the work performed that everyone in the same organisation agrees to call positions by the same job title.	Typically organisation specific	Police Officer
Position	A set of duties, tasks, activities and elements performed by a single worker	Each employed person has a position rather than a job.	Police Officer X, District A
Duty	A Duty is a collection of tasks all directed at general goals of a job.	A thorough job analysis might produce 5 to 12 duties for a typical job	Traffic enforcement
Task	Tasks are collections of activities that are directed toward the achievement of specific job objectives.	A thorough job analysis for a typical job would usually produce from 30 to 100 tasks. Tasks have a clear beginning, middle and end with the end directly linked to the to the goals of the job	Issue tickets to violators
Activity	Activities are clusters or groups of elements directed at fulfilling a work requirement.	When a job is analysed down to the level of activities there could be more than 100 in a typical job and several hundred in a more complex job	Pull motorist over
Element	Smallest unit of work that can be identified as having a clear beginning, middle and end.	Anything smaller would require descriptions of physical motions or sensory processes	Switch on siren and lights

Table 28: Definition of a subset of terms used in job analysis (Brannick et al., 2007)

Whilst Dowling and Hadgraft use Brannick et al's definition of a task, see Table 28, at a higher level they divert from this, and describe a graduate job in terms of three capabilities: technical, process and generic, where capabilities are defined as clusters of tasks (Dowling and Hadgraft, 2013).

In deriving the GCF (Dowling and Hadgraft, 2013) they found that tasks grouped most strongly against generic work processes e.g. investigation, rather than on technical areas. As a result, more tasks are associated with processes than the technical or generic capabilities and in the GCF, an extra level of categorisation was introduced, resulting in three levels: processes, process phases and indicative tasks, as illustrated in Figure 21 where P1 Investigation is a process. Technical and generic capabilities remain described at two levels of categorisation.

P1: Investigation

PROCESS PHASE	INDICATIVE TASKS
1. Defines the scope of the investigation and identifies systems	a. Reaches agreement with client on the goals, objectives, constraints, deliverables and acceptance criteria for the investigation b. Identifies, defines and reaches agreement with the client on the system boundaries – particularly space, time and cost c. Identifies the likely stakeholders and their areas of interest d. Documents the preliminary scope of the investigation
2. Plans the investigation	a. Selects appropriate investigation methods after considering current, new and emerging methods b. Identifies data and information needs, and any knowledge gaps c. Identifies sources of appropriate knowledge and information d. Identifies relevant regulatory frameworks, codes and standards e. Identifies data to be gathered f. Develops sampling strategies, methods, locations and sizes and any specialist input required g. Assesses the resources that may be required for the investigation h. Performs a risk assessment for the investigation (e.g. environmental, financial, legal and OH&S) i. Plans communication strategies for interactions with stakeholders j. Produces a program of activities for the investigation k. Costs the investigation l. Confirms the scope and cost of the investigation and acceptance criteria with the client

Figure 21: The ‘investigation’ process broken down into ‘phases’ (only two shown) and associated ‘indicative tasks’ - from Appendix B (Dowling and Hadgraft, 2013)

The name ‘Graduate Capability Framework’ is somewhat misleading as it implies that it is the capabilities of graduates being described rather than work graduates do.

Applying this framework to a SIP, the technical requirements would be difficult to specify due to the variation in problems and context. ‘Industrial problem solving’ can be considered a process and the three other skills in the SIP working definition i.e. working with others, managing a project and making presentations are judged to align with the generic domains listed in Table 29 below. In contrast to processes, these are only described at two levels and some domains are significantly more extensive than others e.g. communication.

Generic capability domain	No. of indicative tasks per domain
Communication	25
Self-management	11
Project management	10
Innovation	6
Ethics	5
Information	4
Teamwork	4

Table 29: No. of indicative tasks per generic domain for Environmental Engineers

The process phases (Figure 21) would appear to align with SIP methodology stages (Figure 20). Combining this with the knowledge that the majority of tasks align with processes, this would suggest that developing a better definition of the stages of the industrial problem solving process and then breaking each stage down into tasks would identify the majority of SIP tasks.

The generic domain indicative tasks (Dowling and Hadgraft, 2013) would also appear to be on a similar level to those described for processes. The list of domains in Table 29 might appear more extensive than the three generic skills described for a SIP, but analysis of their indicative tasks indicates that there was almost complete overlap with SIPs. For example, the ‘Ethics’ category includes being professional which was part of the SIP assessment, see Table 9. Another observation was that the generic domains are not distinct from one another, e.g. communication was a key aspect of teamwork and project management. This highlights potential categorisation issues if a task strategy is pursued and the differing nature of these activities i.e. throughout a SIP rather than at specific times could make defining tasks in this area more complex.

With a clear rationale for a task approach given earlier in this chapter, and a successful application found to a similar problem, defining SIP tasks was selected as a fundamental step and preferred route in defining skills.

Work analysis methods are mostly used in companies where the person doing the work knows what they need to do. Applying this to the SIP context, we see that students starting the programme do not know what they need to do to undertake a SIP and are still relative novices at the end of the programme in terms of SIP skills. So applying a work analysis approach was not appropriate.

A literature search did not find an evidence-based description of SIP tasks. To identify likely tasks, practice and academic literature was reviewed to cover all aspects of SIP skills and identify those activities able to support a novice.

As previously stated in Chapter 1, SIPs align closely with consultancy-style projects undertaken during MBA programmes (Jennings, 2002). The consulting practice literature was identified as a potential source of SIP activities and two consultancy practice guides (Cope, 2010, Rasiel and Friga, 2001) featured multi-stage high-level process models for undertaking a project. These were selected for review as process models were established earlier in this section as an effective way of describing what needs to be done and can be broken down further.

Cope describes a high-level seven-stage process (Cope, 2010) with each stage broken down into tasks. Whilst all stages are relevant for every project, the tasks are determined by the context and nature of the project. Rasiel and Friga provide a McKinsey perspective (Rasiel and Friga, 2001) that uses a fact-based, hypothesis driven approach to solve business problems that has been successfully used in subsequent managerial employment. An advantage of this approach was that it enabled someone with little prior experience of a business or its context to generate insights making it an effective approach for a novice.

Rasiel and Frifa (Rasiel and Friga, 2001) describe a six stage strategic problem-solving process which starts with understanding the business need, followed by three linked stages of: analysing the problem, managing the team, client and self, and presenting the results of the analysis to the client. The two final stages in this process relate to the leadership and implementation of the solution. As these are typically not involved in a SIP, the McKinsey Strategic Problem Solving process is shown in Figure 22 without these aspects.

Of the two process models described above, the McKinsey approach resonates best with SIPs:

- there was similar fact-based, hypothesis driven approach
- the first four stages appear a close fit with the approach described to the students historically
- the cognitive skill aspects of the 'analysing' stage: framing, designing, gathering and interpreting, map well with the academic requirements of a Masters-level programme
- the 'framing' helps to develop a well-ordered, bounded problem from often ill-structured messy nature of industrial problems
- the generic skills of communicating, working with others and project management are all included
- the three central stages of: analysing, managing and presenting, are emphasised by Rasiel and Friga as they maintain that this practice has proven to be particularly effective. This aligns with the practice thinking of the SIP tutors.

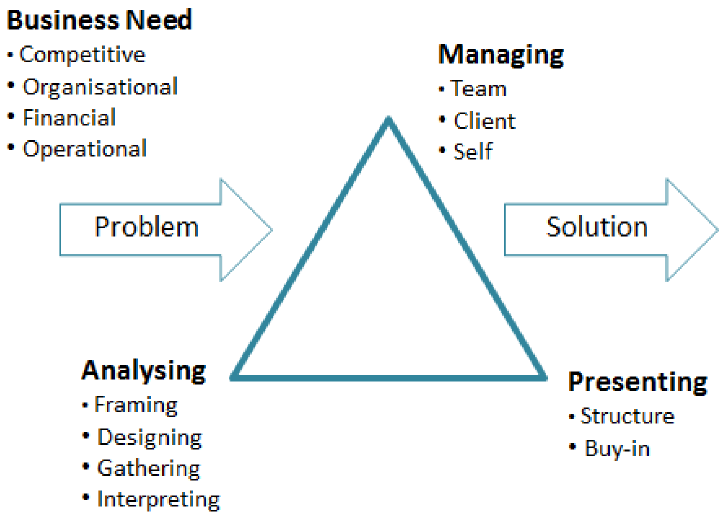


Figure 22: McKinsey Strategic Problem Solving Process – Adapted by Shawcross

There are aspects of a SIP that this high level 'McKinsey' process does not specifically cover that are captured as characteristics of practical problems in Table 1. These include dealing with a lack of information, multiple correct answers or selecting from multiple methods available to obtain an answer. It was assumed that these tasks are embedded in one of their four aspects of 'Analysing'

The visual representation of the 'McKinsey' process appears to relate 'managing' only to 'analysing' and 'presenting'. This implies that the other stages do not require managing or are managed in a different way. It is argued that 'managing', must be a key element throughout a project particularly if it is the same team from project start to finish. This suggests that there are two different classes of tasks, those linked to the process of problem solving and those that take place throughout a project.

The 'McKinsey' process is high level, and in practice would provide little guidance or support to students as the tasks described e.g. framing, are not described in any detail. A perceived strength of the Cope seven stage process is the level of underpinning detail provided per stage – this was similar to the GCF reviewed earlier (Dowling and Hadgraft, 2013).

The 'McKinsey' process is described as a 'strategic problem' solving process. It remains to be investigated whether this would apply to SIP problems considered to be more at the operational rather than a strategic level.

A qualitative study of workplace engineering problems (Jonassen et al., 2006) found that problems were ill-structured, complex and typically involved incomplete and distributed information. They also had vaguely defined, unclear and conflicting goals, non-engineering success standards and constraints, multiple solution methods and multiple criteria for evaluating solutions. The same study (Jonassen et al., 2006) contrasts these with typical problems found in HE engineering programmes which have specified parameters, a single solution and a preferred solution method. This view was similar to other studies comparing ill-defined problems found in the workplace, to the solvable puzzles typically found in academic programmes (Hedlund and Sternberg, 2000) reviewed in Chapter 2 and highlights some real challenges which graduate might find difficult to deal with. Summarising the key differences between academic and real problems that a novice would have to cope with four main aspects emerge:

- Problems are poorly defined and in need of reformulation
- Information may be lacking, distributed or inconsistent
- There are multiple methods available to develop a solution
- There are multiple correct answers each with advantages and disadvantages

Problem solving strategies were reviewed to identify if there were any established methods for solving ill-structured, complex workplace problems. In a study by Woods (Woods, 2000), over 150 published strategies were reviewed. His analysis found that most start with an awareness of the problem and contain up to seven stages including a definition stage, but few were supported by research evidence and only around 7% were designed to work for complex problems. Of these, the most common approach was a nested strategy where the larger problems were broken down into a series of sub-problems that could be solved individually.

There is little difference between a strategic or operational problem solving process in terms of high-level activities as an early problem definition activity will indicate the nature of the problem and thus an appropriate approach.

Of the evidence-based problem solving strategies reviewed (Woods, 2000), the Creative Problem Solving strategy (Isaksen and Treffinger, 2004) contains stages which cover generating and evaluating multiple solutions – one of the important aspects of solving real problems not covered by the 'McKinsey' model. It also includes a 'building acceptance stage' that aligns with the requirement in a SIP to deliver a business case comprising a clear rationale and plan for implementing their solution, including quantified costs and benefits. A visual representation is shown in Figure 23.

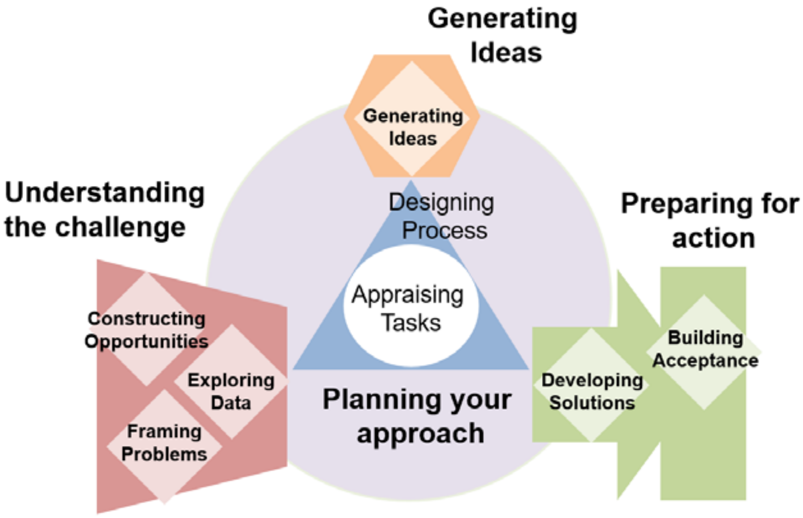


Figure 23: Creative Problem Solving Framework Version 6.1 - redrawn

This framework was a good match with the problem solving aspects of a SIP. There was a close correlation with the McKinsey process on the 'understanding the challenge' aspects, but the Creative Problem Solving process explicitly covers the generating ideas and developing solutions, missing in the 'McKinsey' process.

None of the practice and academic process models reviewed identified high-level tasks related to the information challenges of SIPs. As discussed earlier in this chapter, graduates can be lacking in skills related to dealing with distributed or incomplete data.

A study of core and generic skills in HE and employment (Bennett et al., 1999) identified four broad categories of generic skills, management of: others, self, task and information, where the contents of each category were adaptable to the context. The management of others and task categories align with the SIP skills of working with others and project management in Table 11. 'Management of self' although not listed in the SIP skills in Table 11, maps onto the 'Professional Approach' category as shown in Table 9. As manage-self components are included in the USEM Model, GCF and the 'McKinsey' process and acting in a professional manner was part of the ISMM philosophy there was a strong case for suggesting this should be a SIP skill and one that was required throughout a SIP. Finally, a management of information category if included for a SIP would provide an opportunity to capture the dealing with a number of information related problems such as lack of information.

So grounding and diagnosing the problem from the academic perspective:

- A task approach would be an effective step in describing skills in terms that all stakeholders can relate to
- a number of academic and practice process models have been identified
    - that individually align with some but not all elements of a SIP and the differences between academic and real problems
    - that as a group appear to cover all SIP activities, particularly the industrial solving aspects, and include activities required by novices
- an effective strategy for describing the industrial problem solving process would be process-stages supported by more detailed descriptions of the tasks
- there would appear to be two categories of tasks, those related to the ‘process’ of solving the problem and those related to ‘generic domains’ required throughout a SIP to manage people, the project, information and self.

5.1.3 Diagnosing the problem

The majority of the problem diagnosis was included in the previous sections. In summary: the main problem was the lack of a complete description of SIP skills that all stakeholders could relate to, there is sufficient and appropriate literature from which to generate a description for testing and, SIPs contain a multi-stage problem solving process supported by a number of through-SIP management tasks.

In Research Round 1, it was identified that SIP skills aligned with deliberative professional expertise - see section 2.4.3. Revisiting this description confirms this this view still stands and is aligned with the diagnosis in Research Round 2.

5.1.4 Resolving the problem

Although resolving the problem is usually different for research and practice (Van de Ven, 2007), in this case the main research and practice problems are the same i.e. the lack of a complete description of SIP skills. The research question identified was RQ4: “What tasks contribute to a SIP?”

5.2 Theory Building

As described in Chapter 3 there are three stages in theory building: creating a theory, constructing a theory and justifying a theory (Van de Ven, 2007). Each is considered in turn below.

5.2.1 Creating the theory

Drawing on the problem formulation in the previous section, a plausible description of SIP tasks could be constructed by combining aspects of a number of the models discussed in 5.1.2.3 and aligning them with SIP practice. This is likely to be a process for solving real, ill-structured problems supported by a number of through-SIP domains.

In terms of a theory statement, '*tasks that contribute to a SIP are those required by a novice to solve real, ill-structured problems supported by through-SIP domain tasks relating to project, team, client, self and information'.*

5.2.2 Constructing the theory

The main models to be combined and aligned with SIP practice are the 'McKinsey' Process (Rasiel and Friga, 2001) and the Creative Problem Solving Framework (Isaksen and Treffinger, 2004). In addition categories of generic skills (Bennett et al., 1999) will be applied to complete the high level model in terms of through-SIP domains. To align with practice, the SIP Methodology set out in Figure 20 was supplemented with the description of programme skills in Table 11. The objective was to build a high level framework that can then be subsequently broken down into more detailed levels as used in the GCF (Dowling and Hadgraft, 2013).

The 'McKinsey' Process shown in Figure 22 (Rasiel and Friga, 2001) starts with understanding the business need and the problem before followed by three linked stages of analysing, managing and presenting. Combining this with the historical SIP description a provisional ten-stage process was developed with four through-SIP domains. See Table 30 overleaf. The first stage - make sense of the project - was designed to cover the first part of the McKinsey process. The term project rather than problem was preferred as the SIP process involves defining the problem. The 'analysing' part of the McKinsey process has been captured as five process stages in Table 30 and aligned with the historical view. This adds two new process-stages and extends the historical problem definition stage description to include interpretation of the findings. Two new stages are considered important for novices: 'frame the project' includes creating boundaries for the project and 'design the analysis' enables multiple method aspects to be considered.

Historical view	Modified description with a McKinsey view	
Process Stages	Process Stages	Through-SIP Domains
	Make sense of the project	Manage the project Work with others Manage the client Manage self
	Frame the project	
	Design the analysis	
Data gathering	Gather the data	
Analysis	Analyse the data	
Problem Definition	Interpret the findings and define the problem	
Generate solution	Generate solution	
Implementation	Generate buy-in	
Report & Disseminate	Present project	
	Implementation	

Table 30: Describing a SIP applying the 'McKinsey' process

The 'generate solution' stage was not explicit but implied in the 'McKinsey' process so was included. There was a lack of alignment between the positioning of the 'implementation' stage. In the 'McKinsey' process the 'implementation' stage follows 'presenting' a solution whilst in the historical view it's position reflects its timing related to the final project presentation. In practice, where there was opportunity for implementation, the students would have had to present their proposed solution and win buy-in to enable them to do this.

McKinsey highlight generating buy-in for a solution and this is captured as a new stage in the process. Generating buy-in could also be part of a more formal presentation stage particularly if different client stakeholders were involved. Finally presenting the project to the client and implementation are captured describing a ten-stage process.

Four Through-SIP domains were captured:

- 'Manage the project' (**MP**) - implied in the 'McKinsey' process and part of the ISMM Programme Specification
- 'Work with others' (**WWO**) - part of the ISMM Programme Specification, see Figure 12. This was preferred over 'Manage the team' used in the 'McKinsey' process because it was a team of two where they are equal partners rather than one manage the other.
- 'Manage the client' (**MC**) - part of the McKinsey process and a recognised component of a SIP.
- 'Manage self' (**MS**) - appears multiple times in the literature, including the McKinsey process, and has been identified as part of doing a SIP.

Whilst the new description in Table 30 is more extensive than the historical view, further models need to be included to cover the aspects to support novices. From the Creative Problem Solving Framework, the multi-solution generation and evaluation tasks were added. ‘Generate solution’ becomes ‘generate solutions’ and a new stage of ‘evaluate solutions’ was added. See process-stages 7 and 8 in Table 31 overleaf.

The ‘generate buy-in’ stage in Table 30 was extended to include ‘prepare a business case’. This was intended to capture the building acceptance stage as part of the key task of building a business case, specified in the ISMM programme specification, and missed from the ‘historical view’. The implementation stage in Table 30 was retained as it follows on from building the business case if there is sufficient time within a SIP.

The final historical ‘report and disseminate’ stage was divided into two distinct stages as this involves two different tasks, a presentation and a report, which are delivered sequentially and involve different skills. The result was twelve high-level process-stages, see Table 31.

Management of information remained uncaptured, where particular challenges of dealing with inconsistent, incomplete and distributed information were identified as being difficult for novice engineers. The addition of ‘management of information’ (**MI**) (Bennett et al., 1999) as a through-SIP domain enabled a set of five through-SIP domains to be described at high level, see Table 31 overleaf. At this point aspects of a SIP are captured at what was considered to be at a process phase or domain level as used by Dowling and Hadgraft (Dowling and Hadgraft, 2013).

The result was a construction of a Conceptual SIP Framework (**CSF**) from theory comprising of 12 process-stages and five through-SIP domains.

Historical view	Extended SIP description incorporating multiple views		
Process Stages	Process Stages		Through-SIP Domains
	1	Make sense of the project	Manage the project Work with others Manage the client Manage self Manage information
	2	Frame the project	
	3	Design the analysis	
Data gathering	4	Gather the data	
Analysis	5	Analyse the data	
Problem definition	6	Interpret the data and define specific problem/s	
Generate solution	7	Generate solutions	
	8	Evaluate solutions	
	9	Prepare a business case	
Implementation (if time)	10	Implementation (if time)	
Report and disseminate	11	Present to the company	
	12	Prepare SIP Report	

Table 31: Describing a SIP – Conceptual SIP Framework (CSF)

5.2.3 Justifying the theory

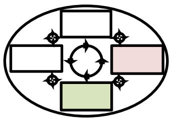
On an empirical basis, the proposed framework would appear to hold true because nothing was found to contradict this. Comparisons were made with the GCF (Dowling and Hadgraft, 2013) and the definition shown in Table 11 to check if anything had been missed. The description in Table 31 was discussed with the academic who agreed that all key aspects of a SIP appeared to be covered.

On a conceptual basis, the combination of two well-established and proven problem-solving processes should provide a solid foundation. As logically these processes were similar, and the integration did not cause any compromise in the logic, then it is deduced that the theory is logically valid.

In terms of the through-SIP domains, the multiple views considered converged to identify five different categories with no apparent conflicts. However, work on developing the CSF focused on the process-stages leaving the five through-SIP domains described at a lower level of detail. This was a cause of concern because an evaluation cannot be made on how these domains connect with each other or the process-stages.

The CSF is recognised as high level and requires validating before further work to break down the process-stages or through-SIP domains into their constituent tasks.

CHAPTER 6: TESTING AND EXTENDING THE SIP DESCRIPTION

Chapter 6	Research Round 2	‘Research design and execution’ and ‘problem solving’ ES research activities 	A research design to answer the question “What tasks contribute to a SIP?” was identified and executed enabling the CSF to be tested at both a high level and task level. Whilst this was successful for the process-stages the through-SIP domains require further investigation.

6.1 Research Design

A variance research design (Van de Ven, 2007) was selected to enable a comparison between the CSF and SIP practice. Factors that impact the design are discussed below.

There are four individual perspectives on what tasks are undertaken in each SIP: two students, a University tutor and a company supervisor. Company supervisors and University tutors would only have partial view as they only observe some of the tasks directly. The students, between them, should be aware of the full range of tasks undertaken during their SIP. So the student perspective was targeted.

The programme includes four differently themed SIPs per student, each undertaken in a different pair. C47 comprised 40 students thus 80 SIPs were scheduled over the academic year, see Table 32. Each SIP was followed by a half-day SIP review session, usually on the Tuesday morning following completion. This provided an opportunity to collect data whilst SIPs were fresh in the mind.

SIP	SIP Theme	Start Date	Duration weeks	No. of SIPs
SIP1	Factory Operations e.g. Layout	29/10/2012	2	20
SIP2	Manufacturing Systems e.g. Lean, Just-in-time	03/12/2012	2	20
SIP3	Marketing & Strategy e.g. market entry for a new product	21/01/2013	2	20
SIP4	Manufacturing Processes or Technology and Innovation Management e.g. new manufacturing techniques	04/03/2013	2	20
Total				80

Table 32: SIPs during C47

An action research approach (Stringer, 2007, Koshy, 2010) was selected as the four SIPs would enable four action research cycles and action research is well suited to the requirement for a participative and collaborative approach in an education context

(Koshy, 2010). All eighty placements could be covered enabling increased confidence of validity of the framework and there was the potential to inform the development of a detailed level framework. This research approach was judged appropriate to deliver the desired results with the resource available.

The ethics related to student participation in this research were considered. It was agreed with the Programme Director that the research could proceed as long as any research tasks were done voluntarily, did not take much time, and the students were kept informed. In addition, as the objectives of the research and teaching were aligned, the research activities could directly support student learning.

One risk was the limited time between SIPs to collect and analyse data, plan and prepare for the next research cycle and, feedback findings to the students. Careful planning and reserving time for these activities was required. A further risk was low student participation resulting in insufficient data. To mitigate this, it was planned to develop a good relationship with the students, provide them with insights for use in subsequent placements, ensure data collection tasks supported their learning and if possible, took place during timetabled SIP review sessions.

An additional challenge was the international nature of the cohort which contained 21 different nationalities and where English was the second language for 75% students. Describing a SIP would require careful attention to language.

Each action research cycle will be described in turn covering the main action research tasks of planning, gathering data, analysing data, communicating the results leading to the planning of subsequent action (Stringer, 2007).

6.2 Action Research Cycle 1

The objective of this cycle was to test the CSF.

The SIP1 review session included a guided reflection process led by the academic. The first step required each student to record ‘What did you do?’ on a two sided form against ten topic headings of: Framing the problem, Project management, Data gathering inside the company, Data gathering external to the company, Analysis of data, Generating solutions, Evaluating alternatives, Developing proposals, Presentation and Teamwork. Under each topic heading there were five to seven prompts. An analysis of these topics found that there was a direct link to eleven of the seventeen aspects in the CSF. One of these topics ‘Framing the Problem’ mapped onto two CSF process-stages, ‘making sense of the project’ and ‘framing the project’ however all the prompts referred to ‘making sense of the project’. This newly discovered, but pre-existing form contained a more detailed description of a SIP, which was found to map well with the CSF.

The advantage of this data collection method, was that it was part of an existing teaching activity during scheduled teaching time and it would provide an indication of what SIP tasks had been undertaken. The downside was the non-prompted aspects might not be covered. As there was only two weeks before SIP2 it was agreed that further testing could be carried out post SIP2 if needed.

The students were informed that the data was wanted to evaluate a CSF and all agreed that we could retain a copy of their “What did you do?” reflection sheet for this purpose. A 100% completion rate was achieved. Each set of statements was analysed to identify what CSF category they related to. This determined whether a student had done a task associated with a particular CSF category. The results are shown in Table 33. The rows shaded in purple are those with no prompts on the Reflection Form.

CSF No.	CSF Task Category	% students
1	Make sense of the project	100
2	Frame the project	10
4	Gather the data	100
5	Analyse the data	100
7	Generate solutions	100
8	Evaluate solutions	90
9	Prepare a business case	100
11	Make a presentation to the company	100
14	Manage the project	100
15	Work with others	100
3	Design the analysis	10
6	Interpret the data and define specific problem/s	55
10	Implementation (if time)	0
12	Prepare a SIP Report	5
13	Manage the client	10
16	Manage self	30
17	Manage information	30

Table 33: % students undertaking tasks in CSF categories

All tasks stated were found to fit in a CSF category. In the prompted (white background) categories there was evidence, in all but one category, that tasks had taken place. The one prompted group where there was limited evidence i.e. 'Frame the Project' was the one mentioned above containing no related prompts.

In the non-prompted (purple background) categories, although the level of evidence was lower, as these were un-prompted categories these levels were likely to be understated and thus good. For example, at the time the data was collected, all students had prepared a SIP report as these had been submitted earlier that day. However, only 5% of students reported doing this task. This may have been because the form was headed 'project process reflection form' and thus students did not comment on the outputs. There was no evidence that 'Implementation' took place. This is known to be a rare occurrence so was expected. It was agreed with the academic that the CSF looked promising and that further testing was required on the unprompted groups above and on different types of SIPs.

An initial visual representation of a CSF was developed based on Table 31 to be able to describe SIPs to the students - see Figure 24.

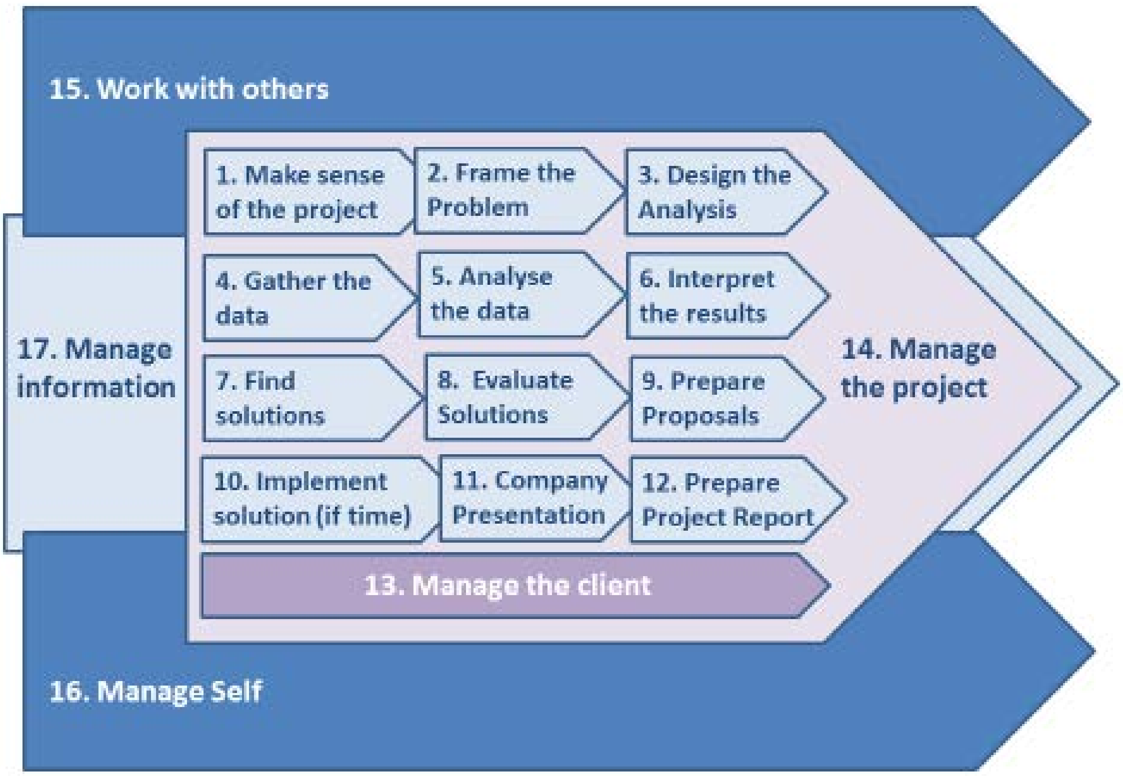


Figure 24: Visualisation of the CSF

The above representation and the main underpinning models were presented to the students prior to SIP2. No immediate concerns were raised about omissions, logic or the visual representation giving further confidence that framework represented the tasks undertaken in SIP1.

Some students also made comments on the ‘What did you do” form about tasks they did not do and what tasks were problematic e.g. interviews where they failed to get all information first time so they had to return. This enabled observations to be made on tasks that students had found difficult. Those who had not struggled appeared to have spent time framing the project and designing the analysis. Such tasks were described in more detail prior to the students undertaking SIP2 suggesting ways these could be undertaken in practice. The information on what tasks students struggle with indicates where the SIP process might be unclear or where further description is necessary.

6.3 Action Research Cycle 2

The objectives for Research Cycle 2 were to confirm the ‘un-prompted’ CSF categories, determine whether the twelve process-stages happened in the order suggested, and whether any tasks could be identified that fell outside the existing categories.

An effective way of describing a task category, is a category description and a list of associated tasks. Such an approach is frequently used for example the GCF, see Figure 21 and UKSPEC (Engineering Council, 2016). To apply this approach, tasks would have to be identified by process-stage, which if tested, would give greater confidence that the CSF was appropriate. By testing tasks, rather than process-stages, an indication of the order in which tasks happened would be gained and any classification issues i.e. where a task did not fit a process-stage could be identified. A category and associated task list approach would generate a detailed framework from which a data collection tool could be constructed and piloted. This could be applied in the third research cycle, leaving the final research cycle to test any unresolved issues. Whilst this approach should enable the objectives of this cycle to be achieved, the data collection would be better during the SIP. This may help avoid potential hindsight bias and would test the CSF from a different ‘bottom-up’ perspective.

A variance research design was selected to compare the detailed task framework with what students experienced in practice. To construct the detailed level framework, tasks were identified from the literature reviewed in section 5.1.2.3, programme documentation and understanding of SIPs. Each of the seventeen categories contained multiple tasks, 52 related to the twelve process-stages and 27 to through-

SIP domains, giving a total of 79. These tasks are listed in the results, shown later in Appendix 2.

A number of issues arose during the development of the framework; finding definitions that would work for all types of SIP, dealing with tasks that are frequently required in some SIPs but not all SIPs, varying levels of importance of some tasks across different SIPs and, achieving the right level and balance in a task category. It was decided that any frequently occurring tasks should be included and when developing guidance for the students, they would be alerted to these issues.

The detailed framework was refined with the Academic before developing a data collection tool. Given the intense nature of a SIP, the data collection tool had to be easy and quick to complete, so a paper based tool was developed that required a tick per task on a daily basis, if they had done that task. An extract for the 'Gather the Data' process stage is shown in Figure 25 below.

Name.. Project Ref No......................

Process Stage			Activity	Placement Day													
				Pre	1	2	3	4	5	S	S	6	7	8	9	10	Post
4	Gather the data	Gather qualitative and/ or quantitative data from a range of sources internal or external to the company	Arranging interviews / meetings														
			Conducting structured / semi structure interviews face to face														
			Undertaking telephone interviews / enquiries														
			Extracting data from company / industry / research reports														
			Extracting required data from company systems														
			Extracting data from public sources - internet														
			Collect new data														
			Other – please add														

Figure 25: Extract from pilot data collection tool

The target was to capture daily data from ten different students as a pilot. Students were asked to record data regularly, preferably on a daily basis, to be able to accurately recall the tasks they had undertaken and identify tasks not in the framework. The main risk was that students would not record data on a sufficiently frequent basis to provide reliable data. This risk was managed by proposing a group of volunteers considered by the academic to be thoughtful and diligent students and by sending reminders.

Twelve students, proposed by the academic, agreed to pilot the tool. They were briefed, reassured that the data was only for research purposes and given a data collection tool. During the SIP, reminders were sent to the group twice each week.

Post SIP, the volunteers were asked to complete a one page questionnaire to capture how data recording had happened, any associated issues and how it could be improved. All students completed the questionnaire. Two students recorded data daily, and the rest every two or three days. Recording was typically done in the evenings and took five to ten minutes. The objective of regular through SIP data capture was achieved, but not on a daily basis. There was full agreement that the terms used in the tool were clear and unambiguous. The issues found included: overlapping or repeated tasks, finding time or remembering, lacking in motivation or being tired at end of day and their ability to match their SIP with the framework at that point in time. Two questions explored the impact of undertaking the research, which eleven students answered. 9/11 said it made them think more about the project process and what they should be doing, 6/11 said they did different tasks as the framework prompted them to consider a range of tasks.

Nine of the volunteers attended a discussion about doing the research. In terms of benefits, they agreed that having a big picture view was the most important as it had helped them to plan, think about the project as a whole and check they were on track. Improvements to the data collection tool were discussed and they suggested it should be shorter, simpler, require less frequent data entry and be computer based.

Of the twelve students, eleven returned their data collection tools. The data was collated and the results are shown in Appendix 2.

The results indicate that all 79 listed tasks were undertaken. 77/79 tasks were done by a minimum of 4 students on at least one day and the remaining two tasks, both from the implementation group, were done by between 1 to 3 students on at least one day. This suggests that the tasks in the detailed framework are relevant and used in SIPs.

The average number of different tasks per student was 71, with the range being 64 to 78, out of a possible 79. This indicates that students were involved in at least 81% of the tasks listed in the framework.

Five variances were identified by four different students. The low variance identification rate of <1% was a concern given this was the first test of the more detailed framework. A possible cause was the style of tool which was designed to be quick to complete rather than thought provoking and reflective.

Each variance is now reviewed. One student identified that they undertook ‘defining the scope of the project’ as part of ‘making sense of the project’ whereas the framework has this task in the subsequent process stage of ‘framing the problem’. Two students suggested new tasks in ‘gather the data’; gather opinions and feedback on current systems and identify practical tools from ‘The Lean Tool Box’ book. The other student pointed out an apparent anomaly in the order of the process steps reporting that they had implemented different solutions in order to evaluate which one would be selected for recommendation to the company. Their other suggestion of a new task was one that was peculiar to the context of that SIP.

The data patterns suggest the overall sequence of the process stages was appropriate and that in the majority of cases, these took place in parallel. The tasks in the through-SIP domains were usually undertaken on a daily basis however, a minority were specific to a particular process stage such as ‘agree project deliverables with client’ in the ‘manage the client’ domain.

The objectives for this research cycle were achieved: all CSF categories were confirmed, no tasks were captured that fell outside of these categories, the twelve process-stages did happen in the order suggested, but many happened in parallel.

The detailed framework and the data recording tool were refined to reduce overlaps and the amount of data recording. An Excel spreadsheet data recording tool was prepared containing 76 tasks, with 56 relating to the process-stages and 20 to the through-SIP domains.

6.4 Action Research Cycle 3

The objectives of this research cycle were to test the framework at both levels against Marketing and Strategy SIPs with all C47 students and all the University tutors involved. This extended testing, both in terms of numbers and with different stakeholders was intended to increase the level of critical review whilst still employing a variance research design.

6.4.1 Testing with the students

The students were briefed about the research and the data recording tool prior to SIP3 with reassurances that the data was for research purposes only and any findings would be anonymised. All students were invited to record their daily tasks in an Excel recording tool entering a ‘1’ in the appropriate cell if they had done the task. Each task category contained an ‘other’ line to prompt the capture of tasks not yet featured in the framework. Reminders about the data recording were sent on four occasions during the SIP and once at the end.

During the SIP3 review, all students were asked to complete a one page questionnaire on how they had recorded their data and whether the task descriptions had made sense. 31/40 completed this, reflecting the level of attendance. 79% had recorded data at least twice weekly with 54% on a daily basis thus giving confidence that data was reasonably reliable. Only three task descriptions e.g. 4.7 collect new data, were highlighted as being ambiguous.

31/40 students submitted completed spreadsheets. The spreadsheet data was summarised using comparable categories with those in the previous action research cycle to enable comparisons and the results are presented in Appendix 2.

The results indicated that all 76 tasks in this framework were undertaken. 74 out of the 76 were done by a minimum of 9 students on a least one day and the remaining two tasks were done by 1 to 8 students on at least one day. Neither of these two tasks feature strongly in Marketing and Strategy SIPs.

Five different variances were reported by three students. These were reviewed with the academic. Four were incorporated into to the framework by either adding a new task or by extending the description of an existing one. The fifth related to a task specific to a particular SIP, so was not included.

The patterns of data again show that the sequence of the process-stages in the CSF happened in practice and many took place in parallel. Process-stages 1 to 3 happen predominantly in week 1, stages 8 to 12 happen predominantly in week 2, and stages 4 to 7 would appear to happen broadly in parallel straddling the two weeks. One aspect to note was that identifying a preferred solution, captured in stages 7 and 8, starts before the results of the data analysis are typically known. Whilst in theory (Isaksen and Treffinger, 2004) you might want to fully understand the situation before identifying a preferred solution, with only two weeks for a SIP in an unfamiliar context it is only by exploring particular solutions that this understanding is developed.

In terms of the CSF, all categories were again confirmed with the exception of ‘manage information’. This was not tested to reduce data collection and increase the focus on the process-stages. No tasks were identified that fell outside of the CSF categories.

The data related to the through-SIP domains showed two distinct patterns. Categories 13 ‘manage the client’ and 14 ‘manage the project’ contained some time related tasks that connected directly with tasks in the process stages. Categories 15 ‘work with others’ and 16 ‘manage self’ the tasks occurred more consistently throughout the SIP and there no overlapping tasks. This difference was intuitively captured in Figure 24 where 13 and 14 were placed closest to the twelve process-stages and 15 and 16 were positioned as underpinning the SIP.

6.4.2 Testing with the tutors

A semi-structured interview research method was selected as this would enable both a focus on the task framework and any new perspectives to be explored. The question set developed for the interviews is shown in Figure 26 overleaf.

Eight University tutors were interviewed after they had marked the SIP reports to avoid any possibility of this having any impact. Each tutor was sent an updated framework, incorporating the results from the previous section, some background information about the research and the list of questions to be addressed. Two interviews were undertaken by video call and the remaining face to face over a period of 4 days from 19^{th} to 22^{nd} February 2013.

The interviews lasted between 30 and 45 minutes, notes were taken by hand and written up shortly afterwards whilst the interview was still fresh in the mind.

Five tutors had multiple years of experience with all types of SIPs and three were new. All confirmed that the CSF appeared to capture the overall range and the general sequence of the process-stages and that the tasks appeared to be appropriate.

Tutor Questions on ISMM SIP Framework

About you as a tutor

1. How long have you been involved as a tutor for ISMM projects?
2. Are there any particular types of SIPs you supervise e.g. TIM, Manufacturing Processes?
3. How many SIPs have you been tutor for this academic year?

Looking at the overall ISMM SIP Framework

4. Does the overall model capture the broad types of tasks that are covered on any project?
5. Are there any tasks from your experience that the model doesn't cover?
6. Can you suggest improvements?

Looking at the framework at the task level

7. Are there any significant tasks that you think are missing?
8. Does the inclusion of any of the tasks surprise you?
9. Are there any tasks that appear unclear / ambiguous?
10. Do the individual tasks feel about the same in terms of weighting?
11. Can you suggest improvements to the framework at this level?

Thinking about how this framework can support ISMM

12. How do you think this framework can help you as a tutor?
13. What do you think are the main benefits of the framework to the student?
14. What issues could there be from wider use of the framework in ISMM?

Any other comments?

Figure 26: Questions for ISMM tutors

In terms of the CSF, there were two significant findings: the start and end point for the framework required clarification as there were tasks that took place before and after those described and, the visual illustration required modification to indicate the inter-relationships between stages and that some stages happen in parallel.

One task not covered was a pre-SIP meeting between the students and their tutor. This was suggested as being critical to the success of a SIP as students developed an understanding of the SIP from the tutor involved in writing the project brief.

A number of tasks were suggested for inclusion in the detailed framework

- identification and use of domain specific knowledge
- determining the tools and techniques needed (pre-SIP)
- completing the report and doing corrections (post-SIP)
- recognising feelings / stress levels of others
- dealing with the political/cultural dimension such as how to identify stakeholders and keep key ones in the loop

- thinking at different levels – strategic / tactical
- developing an effective brief project overview / introduction

6.4.3 Refining the framework

The results of the research were discussed with the academic. As a consequence

- the visual format was modified to highlight the interactions between the process-stage groups and now renamed as the SIP Framework
- the start and end points were clearly defined and required the addition of three new tasks at the detailed level
- each process-stage task description was reviewed and revised if necessary to include suggestions, reduce ambiguity or improve clarity

The visual format of the SIP Framework shown in Figure 27 went through multiple development iterations. The circular arrows were added to indicate the interactions and overlaps between task categories.

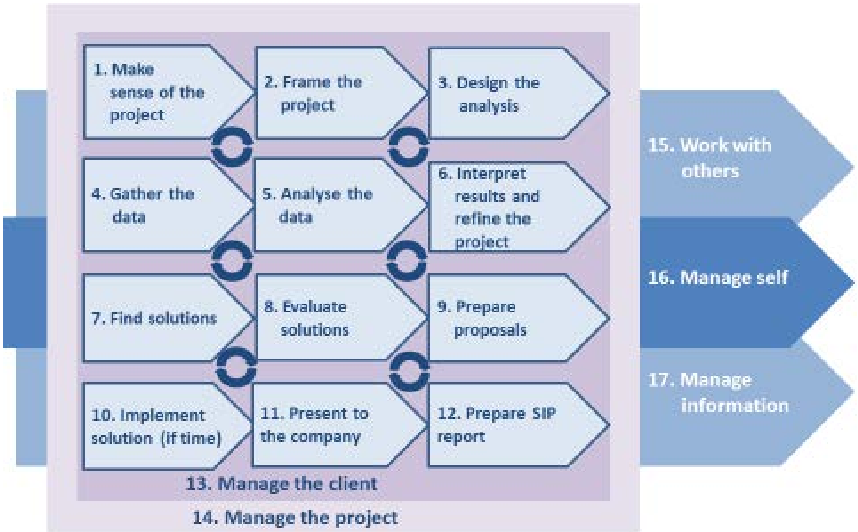


Figure 27: SIP Framework

It was agreed that the process-stages appeared to be captured but there were still challenges with the through-SIP domains. With SIP4 fast approaching it was decided to represent the through-SIP tasks at the domain level only and revisit this in Research Round 3. The time specific tasks in the 'manage the client' and 'manage the project' through-SIP domains were incorporated into the relevant process-stage of the detailed framework and general guidance was captured in two columns at the end as shown in Figure 28.

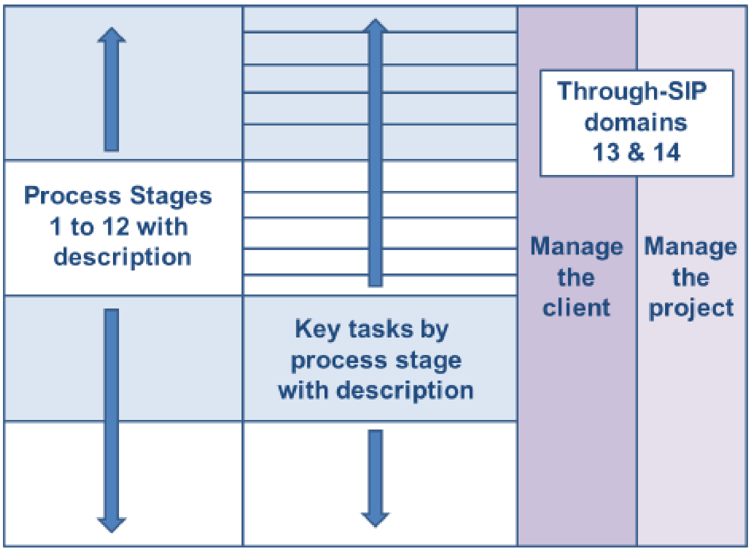


Figure 28: Structure of the detailed framework

The revised detailed framework, given to the students prior to SIP 4, contained 63 tasks related to the twelve process-stages.

The results from this research cycle strengthened the view that the SIP framework was representative and that the detailed task-level framework, focussed on the 12 process-stages, was relevant for the majority of SIPs.

6.5 Action Research Cycle 4

The main objectives of this cycle were to test both frameworks against the final set of ‘Manufacturing Process’ SIPs. With increasing confidence in the frameworks, a notable lack of student motivation for daily task recording and a need for more critical evaluation, a group, rather than individual, review strategy was planned for the post SIP review.

26 students attended and were divided into 6 groups. Each group was given an A1 poster describing four process stages at both levels such as the one shown in Figure 29, and asked to reflect over all four SIPs and suggest improvements to descriptions and identify any tasks not listed.

Process Stage	Description	Ref	Task		
5 - Analyse the data	Critical and rigorous analysis of the data. Generation of visualisations useful to interpret results	5.1	Sort and structure data to enable analysis	**Manage the client** Keep the client informed of planned actions and progress. Ask for access to information and contacts. Discussion and resolution of issues as they arise. *In the mid stages of the project it is essential to discuss your findings, their implications for the project and proposed solutions. This enables you to gage reaction and build support.*	**Manage the Project** Develop an overall project plan as well as detailed plans per stage. Actively manage the project including monitor progress and priorities against plan and make refinements as required *In the mid stages of the project, monitoring progress against plan and reviewing priorities is critical. Some later stages can happen in parallel e.g. presentation preparation and report writing.*
		5.2	Deal with incomplete or inconsistent data – make assumptions		
		5.3	Assess reliability/validity of data and assumptions		
		5.4	Deal with large data sets e.g. those requiring use of macro's		
		5.5	Analyse qualitative data		
		5.6	Analyse quantitative data		
		5.7	Develop visualisations of data		
6 - Interpret results and refine the project	Determine results and consider what these might mean for different stakeholders. Validate results. Refine project specification and objectives if required	6.1	Identify anomalies in data		
		6.2	Consider results in relation to hypotheses / questions posed in 2.3		
		6.3	Draw insights from results and identify further questions or issues.		
		6.4	Validate results from different stakeholder perspectives		
		6.5	Refine project definition, boundary, scope, deliverables etc. as required		
7 - Find solutions	Identify feasible solutions	7.1	Generate ideas using creative (divergent) thinking		
		7.2	Collect ideas of potential solutions from company sources		
		7.3	Search for potential solutions from outside the company		
		7.4	Identify resource, operational and technical constraints		
		7.5	Shortlist feasible solutions / options		
8 - Evaluate Solutions	Select preferred solution/s using a logical and relevant selection procedure. Test suitability and acceptability with stakeholders	8.1	Identify appropriate selection criteria		
		8.2	Test different options to generate performance data		
		8.3	Apply a logical methodology for ranking options		
		8.4	Identify a preferred solution		
		8.5	Discuss with stakeholder/s to validate evaluation and test suitability and acceptability of preferred solution		

Figure 29: Poster capturing framework at both levels

Groups were instructed to agree any 'suggestions' and two groups looked independently at the same four process-stages. The researcher observed the students and rotated around the groups listening to the discussions to confirm the students were doing the task and to sense how critical the discussions were. It was observed that student's drew on their multiple SIP experiences and presented evidence as to why a task should be described in a particular way. This was judged to provide a critical test of the detailed framework. Before ending the activity, the researcher checked that all groups had had sufficient time to cover all tasks on their poster.

The numbers of suggested changes are shown in Table 34. The limited number further increased confidence that the framework provides a good description of a SIP.

To refine the framework each suggestion was reviewed with the academic. The end result was some improved task descriptions and the addition of one new detailed level task giving a total of 64.

	Group 5	Group 6	Group 1	Group 2	Group 3	Group 4
Suggested Changes	Process-stages 1- 4		Process-stages 5 - 8		Process-stages 9 -12	
To definitions	2	0	3	0	3	2
To tasks	1	0	0	3	0	2

Table 34: Numbers of suggested changes post SIP 4.

6.6 Discussion

This research set out to answer “What tasks contribute to a SIP?” In this section, both the method and results are discussed.

6.6.1 Method

The four cycles of action research provided the opportunity to develop understanding through the different sets of SIPs. Of key importance was the relationship with the students and the alignment of objectives as the research tasks assisted them in developing SIP skills.

The most significant challenge of applying this approach was the short time-frames. One advantage of this was that it forced prioritisation decisions on what to undertake in the next research cycle and what could be parked.

The research design was more effective in determining the SIP framework, the twelve process-stages and their associated tasks than the through-SIP domains. This was because the SIP framework and the twelve process-stages were derived from literature which created a holistic view of the area. The through-SIP domain tasks were based on practice observations so only tested a sub-set of the tasks. It was concluded that having a literature informed holistic view of a process stage or domain was important for deriving a framework.

The research design applied in action cycles 2 and 3 was poor at determining what might be missing, probably because the data collection tool did not promote reflective thought. The group review in action cycle 4, along with tutor testing, increased the level of scrutiny and provides increased confidence that most tasks had been identified as only a few minor changes were suggested.

Student feedback on data entry during SIP2 and SIP3 was collected indicating that the majority of students entered data throughout the SIP, spent sufficient time completing it, and understood the terminology. However, around 20% of the data recorded in SIP3 was considered less reliable due to infrequent recording but was judged sufficiently reliable to determine if a task took place or not.

6.6.2 Results

In the SIP framework, the seventeen task categories remained consistent in all four rounds of SIPs with no one identifying a task that fell outside the framework. The only changes were some refinements to descriptions to provide greater clarity. Given the high-level nature and literature underpinnings of the framework this finding was not unexpected.

The recording of tasks during SIPs 2 and 3 enabled the characteristics of the task categories to be examined. This confirmed that the process-stages did occur in the general sequence shown in the framework and that the majority of through-SIP tasks occurred throughout the SIP. It was observed that students often carried out work in several process-stages in parallel and, sometimes looped back to previous stages. This is common in problem solving practice and is indicative of higher levels of student problem solving abilities (Woods, 2000, Atman et al., 1999).

There were four instances when students expressed views that the framework was a poor match with their SIP. On each occasion, the detail behind it was investigated. This revealed that two SIPs accounted for these 4 instances and in both cases the students were given a specific task and not a ‘messy’ problem i.e. build an Excel model, which only involved a subset of the process-stages.

For the twelve process-stages, the list of tasks was subjected to three cycles of testing and refinements resulting in a final list of sixty four tasks. The multiple cycles with increasing breadth and depth of scrutiny, using student, tutor and researcher perspectives provides confidence that a valid view has been achieved.

The testing of tasks in the through-SIP domains in SIP2 and SIP3 indicated that ‘work with others’ and ‘manage self’ appear to be fully ‘through-SIP’ in nature, whereas ‘manage the project’ and ‘manage the client’ have both ‘through-SIP’ and process-stage components. When tasks related directly to a specific process-stage they were listed there and general aspects of these two were captured on the same page – so they were not forgotten by the students - resulting in a format for the detailed framework as shown previously in Figure 28. Alternative presentation formats require exploring and the Capability Cube Model (Dowling and Hadgraft, 2013) provides an example of an effective approach.

Any further break down of tasks was not seen as appropriate. The detailed framework would be more complex and there were would be particular difficulties coping with the range of SIPs. This reflects student feedback, that it was helpful as presented, and could be improved with some examples of good practice for unfamiliar tasks.

The SIP Framework was considered representative across the full range of SIPs undertaken in an academic year. It was more complex than the six-stage methodology previously used to explain a SIP. Its focus on the 12 process-stages, makes it particularly suited to preparing students to solve industrial problems. The final framework is shown below in three parts in Figure 30, which correlate with the three page framework produced.

Process-stage	Description	Ref	Task		
1 - Make sense of project	Assimilate company and project context. Develop a clear understanding of the project brief, key stakeholders and their expectations.	1.1	Discuss project brief with supervisor/mentor and project team	**Manage the client** Keep the client informed of planned actions and progress. Ask for access to information and contacts. Discuss and resolve of issues as they arise. In the early stages of the project it is essential to agree communication methods, frequency, timing and with who. Do not forget to confirm the project brief with client i.e. task 2.4	**Manage the project** Develop an overall project plan as well as detailed plans per stage. Actively manage the project including, monitor progress and priorities against plan and, make refinements as required. It is essential to develop an understanding of each team members strengths and weaknesses to assist with task allocation. Do not forget to keep in touch with your tutor on matters that could have significant impact on the project outcome.
		1.2	Identify key technical knowledge and/or tools/techniques likely to be required and ensure relevant resources are accessible		
		1.3	Assimilate publically available company information		
		1.4	Assimilate market/industry information		
		1.5	Assimilate information about company challenges/issues		
		1.6	Dissect a project brief to determine areas to question		
		1.7	Discuss project brief with company and determine expectations and key stakeholders		
2 - Frame the project	Generate a picture of the project and its component parts. Identify what questions need to be addressed and any hypothesis to be tested	2.1	Define project scope and boundaries		
		2.2	Break down problem /design /investigation into component parts		
		2.3	Identify the questions / hypotheses for each component		
		2.4	Verify project framing and deliverables with key stakeholder/s and rewrite project brief if required ensuring project objectives are SMART.		
3 - Design the Analysis	Select the tools/methods to be used, define the output required from the analysis and identify data requirements.	3.1	Identify analysis tools/methods suitable to answer 2.3		
		3.2	Select most appropriate tools/methods		
		3.3	Define outputs and ensure they are consistent with formats used by the Company for decision making		
		3.4	Identify what data is needed – qualitative and quantitative		
		3.5	Identify sources of data		
4 - Gather the data	Gather qualitative and or quantitative data from a range of sources internal or external to the company	4.1	Arrange interviews / meetings		
		4.2	Conduct structured / semi structure interviews face to face		
		4.3	Conduct telephone interviews / enquiries		
		4.4	Extract data from company / industry / research reports		
		4.5	Extract data from company systems		
		4.6	Extract data from public sources – internet		
		4.7	Capture new data e.g. take measurements, instrument readings etc.		
		4.8	Design, distribute and collate data via survey/questionnaire		

Figure 30: Process Stage Framework – page 1

Process-stage	Description	Ref	Task
5 - Analyse the data	Critical and rigorous analysis of the data. Generation of visualisations useful to interpret results	5.1	Sort and structure data to enable analysis
		5.2	Deal with incomplete or inconsistent data – make assumptions
		5.3	Assess reliability/validity of data and assumptions
		5.4	Deal with large data sets e.g. those requiring use of macro's
		5.5	Analyse qualitative data
		5.6	Analyse quantitative data
		5.7	Develop visualisations of data
6 - Interpret results and refine the project	Determine results and consider what these might mean for different stakeholders. Validate results. Refine project specification and objectives if required	6.1	Identify anomalies in data
		6.2	Consider results in relation to hypotheses / questions posed in 2.3
		6.3	Draw insights from results and identify further questions or issues.
		6.4	Validate results from different stakeholder perspectives
		6.5	Refine project definition, boundary, scope, deliverables etc. as required
7 - Find solutions	Identify feasible solutions	7.1	Generate ideas using creative (divergent) thinking
		7.2	Collect ideas of potential solutions from company sources
		7.3	Search for potential solutions from outside the company
		7.4	Identify resource, operational and technical constraints
		7.5	Shortlist feasible solutions / options
8 - Evaluate Solutions	Select preferred solution/s using a logical and relevant selection procedure. Test suitability and acceptability with stakeholders	8.1	Identify appropriate selection criteria
		8.2	Test different options to generate performance data
		8.3	Apply a logical methodology for ranking options
		8.4	Identify a preferred solution
		8.5	Discuss with stakeholder/s to validate evaluation and test suitability and acceptability of preferred solution

Manage the client
Keep the client informed of planned actions and progress. Ask for access to information and contacts.
Discuss and resolve issues as they arise.
In the mid stages of the project it is essential to discuss your findings, their implications for the project and proposed solutions.
This enables you to sense reaction and build support.

Manage the project
Develop an overall project plan as well as detailed plans per stage.
Actively manage the project including monitor progress and priorities against plan and make refinements as required.
In the mid stages of the project, monitoring progress against plan and reviewing priorities is critical as some stages can happen in parallel.

Figure 30: Process Stage Framework – page 2

Process- stage	Description	Ref	Task
9 - Prepare Proposals	Prepare a clearly argued and comprehensive business case to support your recommendations	9.1	Develop supporting arguments
		9.2	Develop a detailed actionable implementation plan identifying key resources required
		9.3	Develop financial business case
		9.4	Identify and quantify (where possible) benefits, risks and resource requirements
		9.5	Discuss proposals with stakeholders to test recommendations
10 - Implement Agreed Project Solution	Get agreement to implement solution/s and work with appropriate people to make changes and evaluate their success.	10.1	Obtain agreement by appropriate people
		10.2	Make agreed changes
		10.3	Monitor progress of implementation and deal with issues as they arise
		10.4	On completion check changes are fully operational and delivering benefits anticipated
11 - Prepare and deliver project presentation	Prepare and deliver a presentation to the company and supervisor/mentor to a high professional standard	11.1	Prepare the presentation
		11.2	Practice the presentation
		11.3	Identify likely questions and prepare answers
		11.4	Deliver the presentation
		11.5	Capture key points, questions and reactions to the presentation
12 - Complete project report	Prepare and submit project report consistent with report guidelines and make corrections required for company submission	12.1	Agree report structure, format and responsibilities
		12.2	Prepare draft report sections
		12.3	Collate and edit report then submit by deadline
		12.4	Assimilate feedback from supervisor/mentor and make required corrections to report

Manage the client
Keep the client informed of planned actions and progress. Ask for access to information and contacts.
Discussion and resolution of issues as they arise.
In the final stages of the project it is essential to discuss your proposals to build client buy in prior to the presentation.

Manage the project
In the final stages of the project, monitoring progress against plan and regularly reviewing priorities is critical to ensure all essential tasks are completed on time.

Figure 30: Process-stage framework

6.7 Problem Solving

This final ES research activity is the communication of the findings and the interpretation with the intended audience. The intended audiences were those involved in the research being the L&ES academic, tutors and students. Although an opportunity was provided, no students or tutors attended. The findings were discussed and agreed with L&ES academic and the following conclusions agreed.

6.7.1 Conclusions

Seventeen high-level task categories, twelve process-stages and five through-SIP domains were identified and configured into the SIP Framework.

The twelve process-stages were broken down into sixty four tasks to provide a detailed description. Both the SIP and detailed-level frameworks have been validated over eighty SIPs using student, tutor and researcher perspectives. Further breakdown, beyond tasks, was not seen as appropriate. This provides a solid platform to support the teaching and learning related to the solving of problems undertaken in SIPs and can be incorporated into the Induction Module for C48.

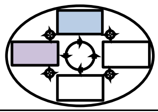
The through-SIP domains require further work to develop a rigorous definition for the SIP context and then to identify the associated tasks. The ‘manage the project’, ‘manage the client’ and ‘manage information’ domains appear to be closely interrelated with the process-stages. Some specific tasks were captured such as 1.1 and 1.7 in Figure 30, as well as tasks at a more general level, see Figure 29 where ‘manage the project’ and ‘manage the client’ guidance was provided related to the process-stages described on that page. The through-SIP tasks for ‘manage self’ and ‘work with others’ remain uncaptured.

The variance research design as deployed was effective in developing the above frameworks but not effective for determining through-SIP tasks. The most significant reason being the lack of underpinning theoretical frameworks.

This SIP Framework, at both levels, describes a complex and demanding challenge which students are required to complete four times as part of their programme. This highlights the requirement to prepare students to undertake SIPs.

With RQ4 “What tasks contribute to a SIP?” not fully answered for through-SIP tasks it was agreed that this should be the focus for Research Round 3.

CHAPTER 7: DESCRIBING THROUGH-SIP DOMAINS

Chapter 7	Research Round 3	Problem Formulation and Theory Building ES research activities 	Conceptual task frameworks were built from literature for three of the five through-SIP domains. Key finding: The two people-centric domains require a different approach.

This is the start of Research Round 3. During Research Round 2, RQ4, “What tasks contribute to a SIP?” was not answered for through-SIP tasks beyond identifying the domains as:

- **M**anage the **C**lient (**MC**)
- **M**anage the **P**roject (**MP**)
- **M**anage **I**nformation (**MI)**
- **W**ork **W**ith **O**thers (**WWO**)
- **M**anage **S**elf (**MS**)

Describing the through-SIP domains is the focus of this research round.

7.1 Problem Formulation

This problem was part of the same problem investigated in Research Round. Whilst some aspects of the problem formulation are the same, some differ. Each of the four problem formulation sub-activities: situating, grounding, diagnosing and resolving the problem are undertaken, but only aspects that differ from Research Round 2 are reported. The grounding and diagnosing activities are combined, as in the previous research round, focussing initially on the practice perspective followed by the academic perspective. The diagnoses are then summarised before resolving the problem.

7.1.1 Situating the problem

This research started with the C47 SIP4 review, continued during the 2013/14 academic year with C48 and concluded during the 2014/15 academic year with C49.

7.1.2 Grounding and diagnosing the problem – practice perspective

There is little captured description of the five through-SIP domains. Over multiple years, the academic has observed that there has been a wide range of abilities to perform through-SIP tasks in each cohort.

The tasks in through-SIP domains are context specific. MP tasks will depend on the size, duration and complexity of a project and MI tasks will depend on the problem and the data available. The practice perspective for each through-SIP domain is very important as this will shape the domain description and hence the associated tasks.

A student view of WWO, MS and MI was explored with C47 in the SIP4 review. The students were asked to record tasks that had been significant challenges during any of their four SIPs. This generated three data sets comprising 45, 28 and 31 tasks respectively from 26 students. MC and MP were not tested as they were considered better understood and time was limited.

An analysis of the data led to the following conclusions:

- there was an extensive range of tasks associated with each domain and significant variation between individuals
- students would appear to experience more challenges with WWO than the other two domains – a possible cause was working with their team member who was likely to be from a different country with a different educational background.
- students describe tasks using different language and at varying levels of detail and, for the WWO and MS domains, behaviours are a key feature.
- through-SIP domains are different in nature and should be considered independent of each other.

The practice view of each domain was captured from discussions with the academic and course documentation, and then compared to the C47 data described above.

Manage the Project (**MP**)

In a SIP context, this means planning and executing the SIP such that the required outputs are delivered on time and at a professional standard. The fixed two-week time frame and the challenging nature of SIP problems require students to manage SIPs carefully to select what tasks need to be done, distribute these between them and then evaluate and collate the outputs to produce a coherent set of deliverables.

Manage the Client (**MC**):

The client for a SIP was the company - however sometimes students see the ISMM Tutor as the client because they undertake the assessment of the SIP.

In the company there may be several key stakeholders e.g. problem owner, day to day supervisor, senior manager. A key MC task was to determine who actually represents the voice of the client and how to deal with differences.

Other key tasks are:

- getting access to the data, information, insights and any other resources required to solve the problem as early as possible in the SIP.
- keeping the client informed of progress, meeting regularly to validate assumptions and test ideas about potential solutions.

This domain is seen as part of MP, but is highlighted separately to emphasise to the students that this domain is critical because of the fixed and short duration of SIPs.

Manage Information (**MI**)

Students work collaboratively with, and manage a wide range of different types of data and information during a SIP. Identifying appropriate data sources, dealing with incomplete data sets and conflicting data are some of the challenges involved. Some aspects of MI e.g. gather data and analyse data are already identified as part of the process stages as they are part of the solving real problems in an industrial context. This through-SIP domain overlaps with multiple aspects of the process-stages.

The C47 exploratory data demonstrated alignment with this practice description.

Work with others (**WWO**)

Students have to work with other people during SIPs with the most significant person being their SIP partner. Students are allocated to SIPs based on individual preferences (SIP briefs are published two weeks in advance to enable students to vote) and then the allocations are refined to ensure, where possible, there was a strong English speaker in each partnership.

Students also have to work with their company supervisor, ISMM tutor and others relevant to solving the problem. Most of these interactions will be information seeking, administrative e.g. setting up a meeting or validating findings.

In terms of a SIP, the WWO domain involves building and maintaining a good working and collaborative relationship with the SIP partner and having an effective transactional working relationship with others.

The exploratory C47 data contained tasks such as communicate ideas, deal with different opinions, understand cultural differences, set and maintain expectations, motivate partner and build a trusting relationship, which demonstrated a good correlation with the practice description.

Manage Self (**MS**)

Students are expected to act in a professional manner – present themselves appropriately, be organised, on time, alert, focussed, open minded and engaged demonstrating a ‘consultant’ rather than ‘student’ mentality (C46 SIP assessment form). Data collected from C47 was a mix of tasks, behaviours and comments covering multiple topics including time management and the management of physical and mental well being. It was agreed with the academic that this data reflected the practice description but such a wide range of tasks made a concise practice description challenging.

In practice there are three types of tasks:

- those that are expected to be done and observed as part of the SIP e.g. be organised and on time,
- those undertaken in the background but essential to delivering a SIP, e.g. manage physical and mental well-being, manage personal affairs,
- tasks that relate to MS in the longer term e.g. personal development. What tasks a student does in the background will vary depending on their individual personal context.

In terms of the research question “What tasks contribute to a SIP?” this raises the question of what counts as ‘contributing’ to a SIP?

The SIP framework starts when students have been allocated into their SIP teams and given a project brief and ends when students submit their report. Students do not just work “office hours”, and as the second category of tasks happens in that period and is essential to the completion of a SIP these tasks should be considered but those in the third category should not.

Summarising the practice perspective: Grounding and diagnosing the through-SIP domains has enabled each domain to be described with respect to the SIP context. MS would appear to be the most wide-ranging domain and WWO has two distinct through-SIP strands.

7.1.3 Grounding and diagnosing the problem – academic perspective

The aim of grounding the problem from an academic perspective was to identify relevant academic and evidence-based practice literature for each through-SIP domain. This was identified as literature that related to:

- a work or a transition from study to work context,
- evidence based 'best practice' or 'standards' adopted by professional bodies.

Before each through-SIP domain is considered, the GCF (Dowling and Hadgraft, 2013) is reviewed as it meets the above criteria, covers a range of generic domains (see Table 29) that aligned with through-SIP domains, and a comparison with the through-SIP domain practice descriptions could identify where there may be similarities, differences or issues. This comparison is shown in Table 35.

Generic Capability Domain	Corresponding through-SIP domain or process-stage	Comment
Project management	MP	Good match at the domain level with 3 of the 10 tasks relevant to a SIP.
Ethics	MS	This relates to being a professional, is a good match with the MS domain and contains 1 task relevant to a SIP
Communication	WWO, PM, Prepare SIP Report	Most aspects connect with the general communication aspects covered in WWO, some connect with report writing and one would be better captured in Project Management. Making presentations is not explicit but implied. The list of indicative tasks now includes descriptions in different formats with subjective elements.
Innovation	Find Solutions, MS and WWO	In this small domain of 6 indicative tasks, 4 align best with process-stage 'Find Solutions'. Of the remaining two tasks one fits best in MS and the other in WWO.
Information	MI + Process Stages	Good match at the domain level and all four indicative tasks are relevant for SIPs. Overlaps with process-stages 'Gather the data, Analyse the data, Interpret the data'.
Self-management	MS, MI,MP and WWO	Whilst more tasks align with MS than any other single domain, one task would appear to align with each of the MI, MP and WWO domains.The task descriptions are provided in different formats and one is not a task i.e. works independently to achieve defined project outcomes.
Teamwork	WWO and MS	Three of the four tasks match with WWO and one to MS. Again variable descriptions of tasks.

Table 35: Comparison of Generic Domains and Through-SIP Domains

This analysis suggests that categorising tasks and task descriptions may be more challenging in through-SIP domains. The GCF classification issues may have occurred for two reasons, firstly there was no description provided of the generic capability domains, so there will be many different interpretations of what these are. Secondly, there are overlapping categories. For example ‘asks questions to seek information’ is both a communication and information related task. The through-SIP domain practice descriptions should limit classification issues and if any occur then the SIP domain descriptions can be revisited and revised if appropriate. Overlapping categories remain an issue.

A typical task description is an action verb followed by a direct object and sometimes followed by a qualifying statement that helps define the task by indicating how, when or why the task is done. (Brannick et al., 2007). Descriptions are also expected to have a clear beginning, middle and end and be directed towards a work goal. Where this criteria was described (Brannick et al., 2007), the work analysis examples provided involved a discrete aspect of a job rather than an ongoing aspect of a job. This is a difference between process-stage and through-SIP tasks.

Through-SIP tasks were seen, in the C47 exploratory data, to feature behaviours, particularly for WWO and MS. Behaviour can be part of a task statement, if used to describe how a task should typically be done (Brannick et al., 2007). How WWO tasks happen in practice will depend on the actual context and people involved. Psychologist Kurt Lewin proposed a heuristic formula $B = f\ (P, E)$ as an explanation of what determines behaviour where B = Behaviour, P = Person and E = Environment. This would suggest that a critical WWO task was making sense of a situation in terms of the person and the context to determine an appropriate course of action.

From the above analysis, describing tasks appears to be more difficult in interpersonal and intrapersonal domains e.g. communication, self-management and team-work. An important distinction to remember is that a task is describing the work to be done and not the person doing the work – this is a different branch of job and work analysis (Brannick et al., 2007).

Each domain is considered in turn.

7.1.3.1 MP – Manage the Project

Project management has been practiced since ancient times (Kwak, 2001, Burke, 2003) but only in the 20th Century have tools and techniques, such as Work Breakdown Structures, been developed and employed to assist in the management of ever more complex projects.

Project Management is a recognised profession today and a number of associations and institutions maintain a body of knowledge that identifies and describes best practice in terms of tools, techniques and skills (Burke, 2003). As this knowledge is reviewed and updated every few years, by both academics and practitioners, these are a source of literature that meet the criteria set out in section 7.1.2 above.

Two recent guides, the Project Management Body of Knowledge (**PMBOK**) guide (PMI, 2013) a global standard from the Project Management Institute (PMI) and the Association of Project Management Body of Knowledge (APMBOK) (APM, 2012), are most often cited in Project Management literature (Burke, 2013). Of these the PMBOK guide is limited to single projects (PMI, 2013) whereas the APMBOK adopts a broader scope (APM, 2012) that covers project, programme and portfolio management. Of these two, the PMBOK is more relevant to the SIP context.

PMI defines project management as the “application of knowledge, skills, tools and techniques to project activities to meet the project requirements” (PMI, 2013). This aligns well with the practice definition established in 7.1.2. The scope of the PMBOK guide is illustrated in Figure 31 overleaf and these project boundaries align well with those in the SIP Framework developed in Research Round 2.

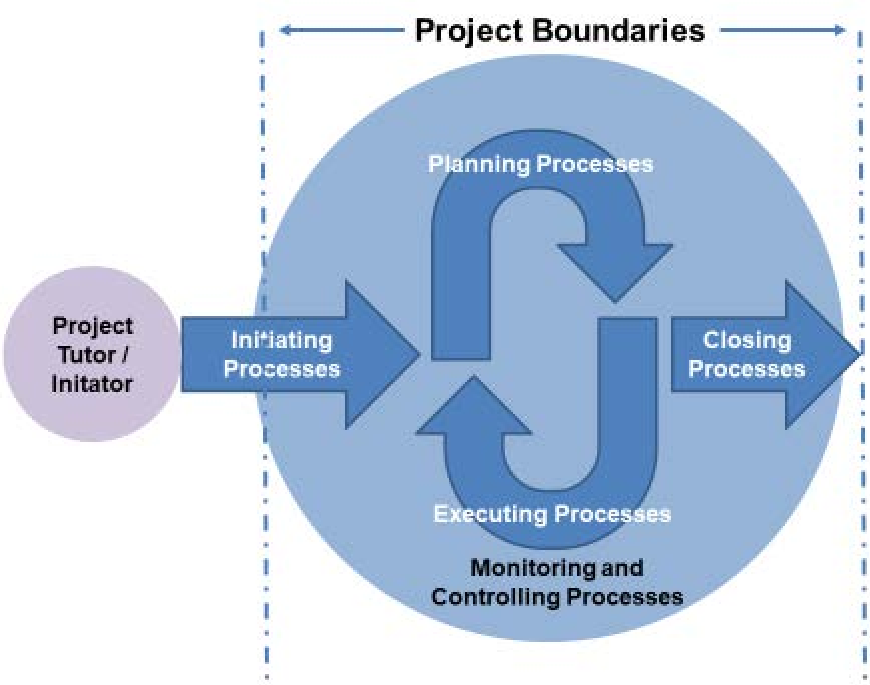


Figure 31: Project Boundaries adapted version of Fig 3-4 (PMI, 2013)

The PMBOK guide describes project management from two perspectives:

- A process perspective identifying five process groups, see Figure 31, and 47 processes as shown in Table 35 overleaf. A process is defined as “a systematic series of activities directed towards causing an end result” and an activity is defined as “a distinct scheduled portion of work performed during the course of a project” (PMI, 2013).
- A knowledge area perspective, with ten management areas, capturing the concepts, terms and activities associated with that area. See Table 36.

Project Knowledge Areas	Project Management Process Groups				
	Initiating	Planning	Executing	Monitoring and Controlling	Closing
1. Integration Management	Develop project charter	Develop project management plan	Direct and manage project work	Monitor and control project work.	Close project or phase
				Perform integrated change control.	
2. Scope Management		Plan scope management,		Validate scope	
		Collect requirements,		Control scope	
		Define scope,			
		Create WBS			
3. Time Management		Plan schedule management,		Control schedule	
		Define activities,			
		Sequence activities,			
		Estimate activity resources,			
		Estimate activity durations,			
		Develop schedule.			
4. Cost Management		Plan cost management,		Control costs	
		Estimate costs,			
		Determine budget.			
5. Quality Management		Plan quality management	Perform quality assurance	Control quality	
6. Human Resource Management		Plan human resource management	Acquire project team,		
			Develop project team,		
			Manage project team.		
7. Communications Management		Plan communications management	Manage communications	Control communications	
8. Risk Management		Plan risk management,		Control risks	
		Identify risks,			
		Perform qualitative risk analysis,			
		Perform quantitative risk analysis,			
		Plan risk responses.			
9. Procurement Management		Plan procurement management	Conduct procurements	Control procurements	Close procurements
10. Stakeholder Management	Identify stakeholders	Plan stakeholder management	Manage stakeholder engagement	Control stakeholder engagement	

Table 36: Adapted Project Management Process Group and Knowledge Area Mapping (PMI, 2013)

A comparison with the terminology defined in Table 28 would suggest that a 'process' in the PMBOK guide was equivalent to a 'task'. However, the PMBOK guide uses three levels of definition whereas the current SIP Framework (see Figure 27) has just two. The implication was that the SIP domains may not all be captured at the same level of abstraction and a further level of classification may be required that would align with either the process groups or knowledge areas in the PMBOK guide.

Of the two perspectives in Table 36 ‘knowledge areas’ are more likely to extend a graduates knowledge as the five ‘process group’ view was somewhat captured in the SIP process stages. In summary, a full practice description of PM relevant to the undertaking of projects was available at three levels of description and some adaption was required for a SIP.

7.1.3.2 MC - Manage the client

An examination of the PMBOK knowledge areas listed in Table 36 identified that integration, scope, communication and, in particular, stakeholder management all contain MC tasks and that the practice conception of MC in 7.1.2 is fully covered.

As a completeness check a review of the client management aspects of consultancy practice literature (Cope, 2010, Rasiel and Friga, 2001) was undertaken but no further tasks relevant to the SIP context were identified. There were insights on how to do tasks in practice such as ‘showing consideration to the client’ (Rasiel and Friga, 2001) which included; work around their schedule, send agenda’s in advance, and show appreciation for what they have done. The practical advice above was considered to be below task level, see Table 28, so would not be captured in the task framework. As this advice was likely to be of value to a novice, it suggests that extending some frameworks to lower levels may be something that requires consideration.

In summary, the PMBOK guide was considered a comprehensive source of SIP MC practice tasks.

7.1.3.3 MI - Manage information

MI has become more important due to significant increases in access to data and information brought about by the digital age.

There is a growing academic field called Personal Knowledge Management (PKM)(Cheong and Tsui, 2011) connected with Drucker’s concept of the ‘knowledge worker’ in the 1980’s and the work of Polanyi in the late 1950’s who first coined the term ‘personal knowledge management’. Thirteen different PKM models are tracked from 1999 (Cheong and Tsui, 2011). They all have different definitions, in part due to the different contexts they were envisaged for, seven are skill/activity centric and six are technology centric.

Of the activity centric models, the one judged most relevant was developed by a group of academics that sought to build a cross-disciplinary approach to information skills. This integrated elements of critical thinking and information literacy with neglected areas of collaborating around, presenting and securing information (Avery et al., 2001). They conceptualised PKM as a set of problem solving skills that have both logical and practical components required for the “problem solving knowledge work of the twenty-first century” (Avery et al., 2001). This framework was designed for use in HE to teach skills that would allow students to develop a deliberate, reflective and adaptable cognitive framework for inquiry and problem solving and was an excellent fit with the MI aspects of a SIP. The framework comprised seven skills: retrieving, evaluating, organising, collaborating around, analysing, presenting and securing information.

Whilst the authors believed this framework was comprehensive, they do not provide evidence that can support this. However in the analysis (Cheong and Tsui, 2011) comparing each model to the four generic knowledge management processes of; capture / locate, create, transfer / share and apply, proposed by Seufert, Back & Krogh (2003) this PKM model was found to cover all areas. Cheong and Tsui go on to recognise the comprehensiveness of Avery et al.’s (2001) model and found in their review that it had influenced many PKM scholars.

The authors (Avery et al., 2001) note the need for the adaption of their generic framework to the particular situation and discipline. They describe skills in terms of “processes involved in the proper exercise of each skill” and from the descriptions provided, tasks can be determined.

In summary, Avery et al.’s PKM model meets the search criteria set out in 7.1.3, was an excellent fit with a SIP and was designed to prepare students for the world of work. There are some overlaps with the ‘Communications Management’ aspects of the PMBOK guide and with some process-stages - particularly ‘gather the data’.

7.1.3.4 WWO - Working with others

The practice view identified that WWO involves building and maintaining a good working and collaborative relationship with the SIP partner and having an effective transactional working relationship with others involved in a SIP.

The search for relevant literature starts with a review of professional expertise and practice literature followed by a review of the graduate employability literature.

The practice view of WWO aligns well with the view of deliberative expertise (Eraut, 1994), previously identified as being a good match with the intended learning outcomes of a SIP, which includes working as a team and undertaking consultation to provide different perspectives and challenge thinking. Eraut suggests that this type of working with others requires careful management to cope with potential alternative agendas as well as good interpersonal skills.

In his review of professional knowledge and know-how (Eraut, 1994) he found that practice-based maps feature non-technical knowledge more prominently than HE syllabus maps and communication, working in teams and working in organisations were given as examples – all considered to be part of WWO. Eraut states these skills can be improved by practice, but require tuning to the person and the context. He suggests this requires professionals to draw on ‘knowledge of people’, to ‘read situations’, and for team work, to ‘get on with people’.

In the PMBOK Framework (PMI, 2013), see Table 36, the Human Resource Management area covers some WWO tasks such as ‘develop the team’ and ‘manage the team’ and suggests interpersonal skills are required including: communication, emotional intelligence, conflict resolution, team building, group facilitation, leadership and decision making. Whilst the PMBOK does suggest some tasks and interpersonal skills relevant for WWO – they appear to be aimed at larger projects and project teams than SIPs so there was a poor match with the practice view of WWO.

A professional practice standard is UK SPEC (Engineering Council, 2016) where ‘Demonstrate effective interpersonal skills’ is the competence that relates to WWO, see Figure 32 and competence is defined as “the ability to carry out a task to an effective standard”. This standard meets the literature criteria in 7.1.3 as it describes the threshold generic competences required for registration as a Chartered Engineer, typically obtained after several years of practice, was cooperatively developed by both academics and industry professionals and is regularly revised – currently in its third revision.

Demonstrate effective interpersonal skills
Communicate with others at all levels.
This could include an ability to: • Lead, chair, contribute to and record meetings and discussions • Prepare communications, documents and reports on complex matters • Exchange information and provide advice to technical and non-technical colleagues.
Present and discuss proposals.
This could include an ability to: • Prepare and deliver presentations on strategic matters • Lead and sustain debates with audiences • Feed the results back to improve the proposals • Raise the awareness of risk.
Demonstrate personal and social skills.
This could include an ability to: • Know and manage own emotions, strengths and weaknesses • Be aware of the needs and concerns of others, especially where related to diversity and equality • Be confident and flexible in dealing with new and changing interpersonal situations • Identify, agree and lead work towards collective goals • Create, maintain and enhance productive working relationships, and resolve conflicts.

Figure 32: UK SPEC – Section D: Demonstrate Effective Interpersonal Skills

UK SPEC was designed for 'engineering practice' in general. Whilst it does include tasks relevant for WWO, such as those in the last statement about working relationships, it was not a good match with the SIP practice view.

Another professional practice standard is The National Occupational Standards for Management and Leadership (MSC, 2008) which claim to capture established best practice standards. These underpin NVQ qualifications and provide detailed descriptions. The standard is divided into 6 areas and 74 units:

- Managing self and personal skills (3 units)
- Providing direction (12 units)
- Facilitating change (6 units)
- Working with people (17 units)
- Using resources (17 units)
- Achieving results (19 units)

Each unit contains a description and lists of skills, outcomes, behaviours, knowledge and understanding – separating out generic and context specific knowledge. The documentation associated with each unit is typically 2 to 3 pages of A4 compared to a paragraph in the PMBOK guide or some suggested activities in UK SPEC resulting in a much more comprehensive description. One reason for the 74 different units is that this standard covers 4 levels of management: team leader, first line manager, middle manager and senior manager, with some units only relevant for particular groups.

Of the six areas, ‘Managing self and personal skills’ connects with MS and aspects of the other five areas (71 units) connect with WWO. The management and leadership perspective of this framework makes applying it to a SIP context challenging where the main focus was solving an industrial problem in a team of two. However, the detail presented in the units highlights, that in a situation where you are working with other people, describing expected behaviour as well as tasks was important. This suggests that a pure task framework for WWO might not be effective in describing what students are expected to do.

In summary, a review of the professional expertise and practice literature reinforced the importance of WWO for a SIP and although a number of tasks were identified, no rigorous, evidence based, frameworks were found at the right level of detail that provided a good match with the practice view of WWO.

In the graduate employability literature reviewed in Chapter 2 the ‘Personal Qualities’ or ‘E’ component of the USEM model (Knight and Yorke, 2004) was found to underpin a graduates’ employability. E contains ‘Emotional Intelligence’ (EI) which covers aspects of relationships and recognising emotions in others see 2.4.4. As this aligns with the WWO practice view and is mentioned as a key interpersonal skill in the PMBOK literature, this area is reviewed.

EI first appeared in the early 1990’s conceptualised as a set of abilities to do with emotions and the processing of emotional information (Salovey and Mayer, 1990). They suggested that individuals differed in these abilities and this could impact on their level of skills. Goleman popularised EI (Goleman, 1996) and then developed it further (Goleman, 1998, Goleman et al., 2002) taking an emotional competencies approach i.e. EI is something that can be learnt, combined with insights emerging from the field of Neuroscience. Whilst some of Goleman’s strong claims were contested (Mayer et al., 2000) EI is now a widely accepted and adopted concept, particularly in working life.

Multiple academic models of EI have been developed taking primarily ability, trait or competence approaches (Palmer et al., 2008). Whilst academics continue to seek a model that can be definitively proven and resolve connections with models of intelligence and personality, it is the mixed models of Bar-On and Goleman (Shanwal and Kaur, 2008, Mayer et al., 2000) that are broader in scope and would appear to resonate more with practice. Of the two, Goleman's Emotional Competence Framework (Goleman, 1998) was considered the most appropriate for preparing students for the world of work as it refers to aspects that can be learnt and was developed with the work context in mind.

Goleman's Emotional Competence Framework was derived by combining and distilling findings from a range of both practice and academic sources (Goleman, 1998) that covered personal competence (how we manage ourselves) and social competence (how we handle relationships). This framework was further refined and simplified (Goleman et al., 2002) but through a leadership lens. On comparison of the two frameworks and detailed descriptions it was concluded that the earlier 1998 version was more relevant to the SIP context where the social competence aspects relate to WWO and the personal competence aspects relate to MS.

The 1998 Emotional Competence Framework was structured as follows:

- personal competence (how we manage ourselves)
    - self-awareness,
    - self-regulation
    - motivation
- social competence (how we handle relationships)
    - empathy
    - social skills.

Goleman claims to have identified five dimensions of EI (Goleman, 1998) that make a unique contribution to job performance which are interdependent, generic and hierarchical. In terms of a hierarchy, self-awareness was crucial for both self-regulation and empathy and all four aspects are required for social skills.

Social Competence (Goleman, 1998) captured in Figure 33 overleaf is the part of his EI framework that best represents WWO. It was informed by competence models from

121 organisations world-wide and the social skills here connect well to those in the professional practice literature reviewed previously.

Social Competence
These competencies determine how we handle relationships
Empathy
Awareness of other's feelings, needs and concerns
Understand others: Sensing others' feelings and perspectives, and taking an active interest in their concerns
Developing others: Sensing others' development needs and bolstering their abilities
Service orientation: Anticipating, recognising, and meeting customers' needs
Leveraging diversity: Cultivating opportunities through different kinds of people
Political Awareness: Reading a group's emotional currents and power relationships
Social Skills
Adeptness at inducing desirable response in others
Influence: Wielding effective tactics for persuasion
Communication: Listening openly and sending convincing messages
Conflict Management: Negotiating and resolving disagreements
Leadership: Inspiring and guiding individuals and groups
Change catalyst: Initiating or managing change
Building bonds: Nurturing instrumental relationships
Collaboration and cooperation: Working with others toward shared goals
Team Capabilities: Creating group synergy in pursuing collective goals

Figure 33: Social Competence Framework (Goleman 1998)

There are concerns about the validity of this framework, as detailed evidence was not provided on how it was derived or tested. Furthermore, a rigorous definition of how the term competence was used was not provided beyond differentiating between pure cognitive competencies like analytic reasoning and emotional competences that combine both thought and feeling.

In terms of alignment with the WWO practice view, a detailed analysis found that 3/5 ‘Empathy’ and 5/8 ‘Social Skills’ aspects did align but the general work context associated with this framework and the lack of underpinning assumptions and evidence would make it difficult to configure to the SIP context.

Goleman has since developed his work on Social Competence (Goleman, 2006) suggesting a further framework rethinking the concept of ‘Social Intelligence’. However, this is conceptual and, in the authors view, lacks resonance with practice.

In summary, interpersonal skills was the term most often used in the professional literature but this only covers part of the SIP WWO conception and no suitable evidence-based framework has been found that aligns with the WWO practice view.

7.1.3.5 MS - Managing self

MS comprises a wide range of tasks. The academic literature in this area comes from many fields including psychology and management but was typically focussed on a single aspect rather than many, and related to general work contexts rather than something as specific as a SIP.

Some literature has attempted to cover multiple aspects, an example being Goleman (Goleman et al., 2002) who identifies personal competence or how we manage ourselves as shown in Figure 34. This covers some but not all aspects known to arise in a SIP. It also provides a person centric rather than a work centric view – i.e. what should a person do to manage their self as opposed what should a person do as part of their work – the perspective sought in this study.

The self-development practice literature is extensive e.g. time management, personal effectiveness. Much this literature covers aspects of MS but little:

- is evidence based,
- describes the full context in which the suggested practice was found to be successful
- has a focus on the transition from education to work,
- covers the wide range of tasks that were highlighted in the data or adopts a work centric view.

Personal Competence
These capabilities determine how we manage ourselves
Self-Awareness
Emotional self-awareness: Reading one's own emotions and recognising their impact, using "gut sense" to guide decisions
Accurate self-assessment: Knowing one's strengths and limits
Self-confidence: A sound sense of one's self-worth and capabilities
Self-Management
Emotional self-control: Keeping disruptive emotions and impulses under control
Transparency: Displaying honesty and integrity; trustworthiness
Adaptability: Flexibility in handling change
Achievment: The drive to improve performance to meet inner standards of excellence
Initiative: Readiness to act and sieze opportunities
Optimism: Seeing the upside in events

Figure 34: Personal Competence (Goleman et al., 2002)

One of the broader based guides aimed at new and experienced managers (Pedler et al., 2007) covers multiple aspects of MS including self-knowledge, emotional resilience and being proactive. This also has a limited research base, again does not cover the range of MS aspects known to arise in a SIP. Whilst it might provide a source of MS tasks, an appropriate framework was not found.

In the professional literature, UK SPEC contains two sections that cover aspects of MS. In Section D, as part of ‘Demonstrate interpersonal skills’ there is “know and manage own emotions, strengths and weaknesses” (Engineering Council, 2016), see Figure 32. Further tasks are within Section E about personal commitment to professional standards and obligations which are shown in Figure 35. Whilst E2 is part of a SIP, E4 is not – see 7.1.2.

E: Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment.
E1 Comply with relevant codes of conduct.
This includes an ability to: • Comply with the rules of professional conduct of own institution
E2 Manage and apply safe systems of work.
This could include an ability to: • Identify and take responsibility for own obligations for health, safety and welfare issues
E4 Carry out and record CPD necessary to maintain and enhance competence in own area of practice
Including: • Undertake reviews of own development needs • Plan how to meet personal and organisational objectives • Carry out planned (and unplanned) CPD activities • Maintain evidence of competence development • Evaluate CPD outcomes against any plans made
E5 Exercise responsibilities in an ethical manner.

Figure 35: Extract of MS related aspects of Section E of UK-SPEC

Examining the National Occupational Standards for Management and Leadership (MSC, 2008), discussed previously (7.1.3.4), one area was called ‘Managing self and personal skills’. This does contain task descriptions but they are more relevant to people in full time-employment and their longer-term personal development. The GCF (Dowling and Hadgraft, 2013) discussed previously (7.1.3) suggests some tasks relevant to self-management which would be relevant to a SIP however the descriptions require adaption to a SIP context.

The broadest framework found was developed by Pedler and Boydell (Pedler and Boydell, 1999) see Figure 36. This combines the ‘self-development notion’ that there are four aspects to maintain and develop: health, skills, action and identity (Pedler and Boydell, 1999), with three classic self-processes: thinking, feeling and willing, featured in the work of Rudolf Steiner and in conventional psychology (cognitive, affective and conative domains) (Boydell, 2014). The framework resulted from research undertaken for the Manpower Services Commission, not now accessible (Boydell, 2014).

Although this takes a person-centric view, the framework would appear to cover the range of issues the students experience. In the published framework this is populated by characteristics or attributes that are required if you are successful at managing either yourself or others (Pedler and Boydell, 1999) that had been derived from the Manpower Services Commission Research referred to above. However, this framework does not meet the criteria set out at the beginning of the chapter.

<table>
<tr><th></th><th></th><th colspan="3">Inner processes that require managing</th></tr>
<tr><th></th><th></th><th>Thinking</th><th>Feeling</th><th>Willing or Doing</th></tr>
<tr><td rowspan="4">Aspects of self that require managing</td><td>Action in the world: getting things done</td><td>Ability to make your own decisions, for yourself, as well as being open to suggestions and feed back from others. Decisions made with an understanding of the way in which your actions affect other people and have consequences for them as well as for you.</td><td>Concern both for your own interests and for those of other people - thus, making moral decisions</td><td>Going out and taking initiatives; courage.
Managing and transforming setbacks, disappointments, frustration;
determination.</td></tr>
<tr><td>Identity, self</td><td>Personal values, ethical and moral standards, and philosophical, spiritual and /or religious beliefs. Awarenss and understanding ot these and of other aspects of self.
Knowing yourself.</td><td>Recognising your strengths and rejoicing in them; accepting yourself in spite of your weaknesses. Valuing yourself</td><td>Self-motivation, purpose in life, sense of security, faith and hope.
Being yourself.</td></tr>
<tr><td>Skills</td><td>Mental and conceptual skills; e.g. Memory
Logic
Creativity
Intuition</td><td>Interpersonal
Social
Expressive
Artistic</td><td>Physical
Mechanical
Technical</td></tr>
<tr><td>Health: a sound mind in a sound body</td><td>Holistic thinking which includes avoidance of simplistic stereotyping and compartmentalising: recognition of the way in which things are interrelated and interdependent: thinking in terms of 'both…and…'. Ability to remain open-minded, to suspend judgment.</td><td>Awareness and acknowledgement of feelings (you have feelings, rather than feelings having you). Balance, inner calm.</td><td>Physical exercise, diet, nutrition.
Healthy habits and lifestyle</td></tr>
</table>

Figure 36: Managing Yourself Framework – from Pedler and Boydell, 1999

In summary, no suitable evidence-based framework was found that aligns with the MS practice view.

7.1.4 Diagnosing the problem

The bulk of the diagnosis has been incorporated in the previous sections. In summary

- Frameworks have been identified that cover MP, MC and MI
- For MI the framework is focussed on students solving problems and their transition to the world of work so requires less configuration for a SIP than the PMBOK framework for MP and MC, designed for practising project managers.
- There are two types of tasks in MP, MC and MI – specific process-stage tasks and those required throughout a SIP. Some of the specific process-stage tasks are already captured in the relevant process-stage.
- Producing a consolidated SIP framework from multiple frameworks will require care to manage overlaps and consistency of task and task level descriptions.
- The WWO and MS domains are broader multi-component domains and no frameworks were found that cover these areas with a rigorous evidence base. A suggested reason was that these domains are particularly context sensitive and that specific SIP frameworks need to be constructed.

7.1.5 Resolving the problem

The research question remains as ‘What tasks contribute to a SIP?’ with a focus on though-SIP domains to construct a task-centred SIP framework.

These domains could be described to students in terms of context relevant, evidence-based task frameworks similar to those developed for the process-stages. This would enable students to consider the range of tasks they ‘should do’ and familiarise themselves with language applied in industry. This would also mirror practice in industry where large companies often have their own frameworks to facilitate a common understanding and assessment of key company domains such as leadership.

For MP, MC and MI evidence-based frameworks were found that break down these domains into tasks. These can be used as a basis for developing SIP configured task frameworks.

For MS and WWO, there are no evidence-based frameworks that align with the SIP context. To resolve this problem, specific frameworks could be created from task data.

7.2 Theory Building

The theory proposed in Chapter 5 was '*tasks that contribute to a SIP are those required by a novice to solve real, ill-structured problems supported by through-SIP domain tasks relating to project, team, client, self and information'*. Work now continues on this theory with a focus on through-SIP domains.

Of the three theory building stages: creating, constructing and justifying (Van de Ven, 2007) it is the constructing stage that is continued below for the MP, MC and MI through-SIP domains. WWO and MS are addressed in Chapter 8.

7.2.1 MP – Manage the project

The PMBOK Framework in Table 36 was identified as an appropriate base for a MP framework. The PMBOK was designed for project managers carrying out a wide range of projects and not novices undertaking SIPs, so adaption was required.

Each task was reviewed by the researcher and the academic, then discussed to determine if this was part of MP. In cases of disagreement, the academics view prevailed. As tasks included and excluded from the framework could be tested on the students this would not influence the final MP framework.

As a result:

- three of the ten areas were removed i.e. cost, quality and procurement management as these were seen to be company responsibilities. However, it was considered that students were responsible for the quality of their work.
- Human Resource Management was changed to Team Management. The process of 'acquire project team' was removed as this was not part of a SIP. 'Plan human resource management' was replaced by 'assess project team capability', considered to be the equivalent SIP task.
- For Communications Management the 'control communications' task was removed as it was considered beyond scope.
- In Risk Management the 'perform quantitative risk analysis' was removed as it was not taught in the ISMM programme and students were unlikely to have the specialist knowledge and skills to undertake this.

This left 7 knowledge areas and 33 tasks as an initial MP Framework see Table 37. The tasks are strongly interconnected with those in the process-stages as many were time dependent. This aligns with the findings in Chapter 6, and the development of the GCF (Dowling and Hadgraft, 2013) that tasks predominantly group around processes.

MP Task Clusters	MP Tasks
Integration Management	Develop Project Charter, Develop Project Management Plan, Direct and Manage Project Work, Monitor and Control Project Work, Perform Integrated Change Control, Close Project
Scope Management	Plan Scope Management, Collect Requirements, Define Scope, Create Work Breakdown Structure (WBS), Validate Scope, Control Scope
Time Management	Plan Schedule Management, Define Activities, Sequence Activities, Estimate Activity Resources, Estimate Activity Durations, Develop Schedule, Control Schedule
Team Management	Assess Project Team Capability, Develop Project Team, Manage Project Team
Communications Management	Plan Communications Management, Manage Communications
Risk Management	Plan Risk Management, Identify Risks, Perform Qualitative Risk Analysis, Plan Risk Responses, Control Risks
Stakeholder Management	Identify Stakeholders, Plan Stakeholder Management, Manage Stakeholder Engagement, Control Stakeholder Engagement

Table 37: MP Task Framework

A new categorisation level of task cluster was introduced at the equivalent level of a process-stage to describe domains.

This framework was considered ready to be tested to determine if it reflected the MP tasks students do. All the tasks are described in a short form with an action verb and a direct object. There was some concern if this was sufficient detail for testing.

7.2.2 MC – Manage the client

The same process in 7.2.1 was applied to MC to determine which parts of the MP framework applied to MC. The significant aspects of MC were agreed and are shown in Table 38 below. These comprise four knowledge areas i.e. stakeholder, integration, scope and communications management and nine specific tasks.

MC Task Clusters	MC Tasks
Integration Management	Develop Project Charter, Develop Project Management Plan, Perform Integrated Change Control, Close Project
Scope Management	Define Scope, Validate Scope
Communications Management	Manage Communications
Stakeholder Management	Identify Stakeholders, Manage Stakeholder Engagement

Table 38: MC Task Framework

This was framework was now considered ready for testing.

7.2.3 MI – Managing information

Adapting the PKM framework (Avery et al., 2001) required an analysis of their skill descriptions to identify tasks. The results were discussed and agreed with the academic, resulting in the framework in Table 39. There are overlaps with some process-stages particularly: gather the data, analyse the data, interpret results and presentation to the company. This was expected, given the problem solving focus of this framework and the previous finding, that tasks group around processes. In addition, collaborate around information, connects with WWO.

In discussions with the academic it was agreed this appeared to be a good fit for a SIP, it highlighted aspects previously uncaptured such as 'secure information' and was ready to be tested.

MI Task clusters	MI Tasks
Retrieve information	Search for information
	Gather information from different sources e.g. print, electronic, people
Evaluate information	Evaluate relevance
	Determine quality and status of information
	Deal with incomplete or inconsistent data
Organise information	Determine an appropriate way to organise information given the context
	Undertake regular and systematic organisation of information
Collaborate around information	Determine appropriate information/communications systems
	Determine procedures for information exchange, retrieval and cataloguing
Analyse information	Determine an appropriate method and tool for data analysis e.g. excel
	Process the data
	Analyse results to extract insights
Present information	Determine an appropriate format to communicate to the audience
Secure information	Protect information
	Keep all sensitive data information confidential

Table 39: MI SIP Framework

7.3 Conclusions

Practice definitions of the through-SIP domains were generated. Three were found to be aligned with exploratory C47 data. Data was not available to test the other two.

Task frameworks were developed for the three through-SIP domains, MP, MC and MI with MC identified as a subset of MP.

The MP and MI through-SIP frameworks have academic underpinnings and an evidence base. Of the underpinning frameworks: the PMBOK was considered the most mature and the MI framework aligns better with the student to work transition and the specific SIP context.

In contrast, no WWO or MS framework was found that met the required criteria. Both WWO and MS appear to be broad and multi-strand domains.

The 17 categories of the SIP framework presented in Figure 27 are not presented at a consistent level because the process-stages 1 to 12 align better with a task cluster in a through-SIP domain framework than the through-SIP domain itself. This results in five high level domains: 'Do the project' which now comprises the process stages, 'Manage the Project' which comprises MC and MP and then the other through-SIP domains of WWO, MS and MI. Applying this thinking then a new representation of the high level SIP Framework would appear as shown in Figure 37 below.

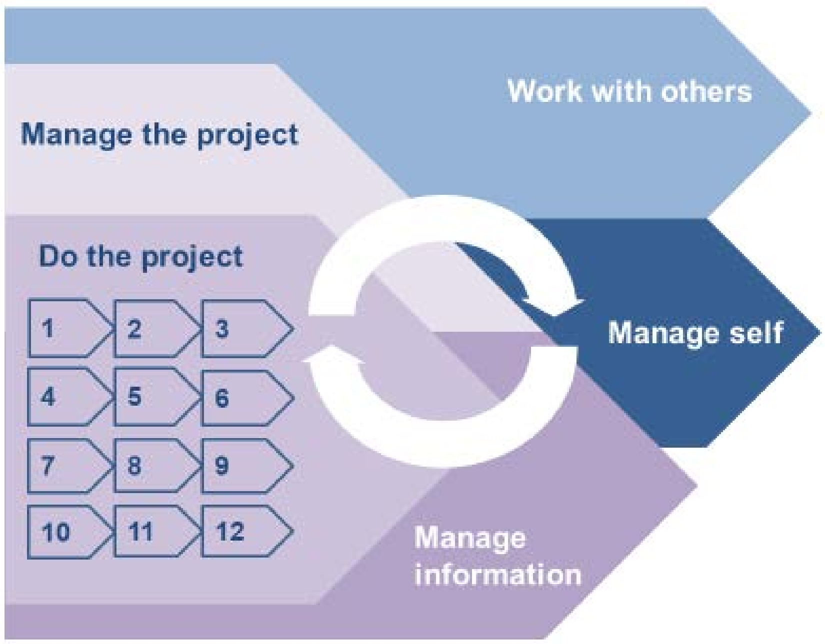
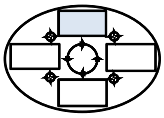


Figure 37: SIP Framework – new representation

The three purple coloured categories are closely interlinked and represent the delivery-centric domains whilst the two blue coloured categories capture the people-centric domains that underpin the delivery of the project. The large circular arrow depicts the interconnectedness of all five domains.

CHAPTER 8: DESCRIBING PEOPLE-CENTRIC THROUGH-SIP DOMAINS

Chapter 8	Research Round 3	Theory Building ES research activity 	An evidence-based description of the people centric domains of WWO and MS was constructed using a grounded theory approach. This approach enabled both preliminary theory building work and an answer to RQ4: “What tasks contribute to a SIP?”

8.1 Research Design

Instead of the previous top-down approach of deriving a framework from theory and validating it empirically, a bottom-up approach was undertaken where a framework was derived from empirical data because no relevant, evidence-based frameworks were identified – see Chapter 7. Grounded Theory, is a ‘bottom up’ research strategy or methodology where the researcher derives an abstract theory of processes, activities or events grounded in the views of the participants (Creswell, 2009, Urquhart, 2013). Many researchers use the first part of this methodology as a way to systematically analyse qualitative data (Urquhart, 2013) rather than go on to develop theory. As a systematic analysis of data would answer the research question and contribute to theory building with the resources available, a grounded theory approach was selected.

A drawback is that this approach will only identify tasks that students say they did, and not include those that a ‘professional’ with several years of experience should do. However, the analysis could point to topics where literature is available that could suggest indicative tasks in these domains and hence, help overcome this drawback.

Advantages of this methodology are that it is relatively easy to collect student data, the analysis will enable the domain practice description– see 7.1.2 – to be more rigorously tested and the researcher has prior experience of undertaking systematic coding.

8.2 Research Method

A five-step research method, outlined below, was designed to collect and analyse the WWO and MS data sets .The method is set out first before describing its execution and the results generated for each domain.

8.2.1 Step 1 – Data collection

The data collected should describe what through-SIP tasks students do during SIPs. As this involves cognitive and physical tasks, the student is the most appropriate source of data. The options for data collection included, students recording tasks during SIPs or post SIP, during the SIP review or via a survey.

The strategy of collecting data in SIP reviews was selected as:

- it had proven to be effective in terms of high response rates
- would not distract the students whilst undertaking their SIPs
- would be quick to carry out
- the majority of the 84 SIPs in the C48 academic year could be covered.

The exploratory study discussed in section 7.1.2 found that even though individual students only described three tasks, these varied significantly, resulting in a wide range of task descriptions across the cohort. It was assumed, that by repeating this strategy for each SIP, that a wide-ranging data set would be captured.

8.2.2 Step 2 – Preliminary data analysis

All task statements to be entered into a spreadsheet and, any multiple task statements to be separated. Each statement to be analysed to identify the 'task statement' components (see 7.1.3 i.e. action verb, direct object and qualifying statement) and further information volunteered about context or behaviours.

A comparison to be made with the practice domain description (see 7.1.2) to identify any variances. If no variances are found then alignment is achieved. If variances are found then an investigation is required.

8.2.3 Step 3 – Developing the coding framework

Coding will be difficult because a task description has two core components plus qualifying statements. The 'direct object' is likely to be the better primary code because these are specific recognisable aspects e.g. SIP report in contrast to action verbs e.g. structure, write, review, which need either a direct object or context to make sense.

The direct objects can be analysed and categorised using grounded theory principles of letting the categories emerge from the data and applying constant comparison to determine a categorisation framework. This framework should be peer reviewed to identify any categories that are not distinct and revised.

8.2.4 Step 4 – Coding the data and confirming the framework

Each statement can be coded using the framework developed in Step 3. From experience this process generates potential refinements to the framework. An iterative process of code then review is likely, before a final framework and coding is achieved i.e. when there is good fit between the data and the framework, demonstrated by each statement identifying with a single framework category.

8.2.5 Step 5 – Identifying the tasks

All the action verbs associated with a particular 'direct object' code can then be collated and analysed to identify specific tasks that students do. Care is required to identify tasks at an appropriate level as it is known from the exploratory data sets that students describe tasks at different levels of granularity e.g. 'communicate' at a high level and 'select phrasing to convey meaning of results' at a detailed level.

8.3 Data Collection – Step 1

In the SIP1 review, students were asked to capture three aspects of WWO and MS that were key or challenging tasks. The students wrote on post-it notes and stuck them on the relevant flipchart. This approach enabled those present to see the responses and the academic to select some for class discussion.

The data sets generated are in Table 40. On evaluation, 3.4% of responses were difficult to interpret meaningfully as students had provided single word answers but the data sets were judged as wide-ranging by both the researcher and academic. A similar data collection strategy was agreed for SIP2 but students would be asked to provide multi-word explanations.

	No. Students providing data	No. of WWO Statements	No. of MS Statements
SIP1	95%	120	108
SIP2	79%	72	70
SIP3	81%	99	84
SIP4	48%	53	49
Total		344	311

Table 40: Data points captured for WWO and MS

Following SIP2 data collection, despite the request for multi-word explanations, it was concluded that the limited writing space and anonymous process caused some responses to be too high level to be interpreted meaningfully and around 1% were judged flippant. After SIP3 and SIP4, students were given individual forms to complete by hand. On evaluating the data sets this method of collecting the data provided a better quality of statement from the students.

Whilst the numbers of students attending the post SIP review sessions fell, data sets with over 300 hundred data points were achieved for each domain that covered the full range of SIPs carried out in the academic year.

Evaluating the data collection

An 85% overall response rate was achieved for the first three SIPs. This dropped to 76% over four SIPs due to the low numbers attending the final SIP review. Every student in the year contributed at least one set of data and the high response rates ensured that a minimum of 76% or 64 SIPs were represented.

Students were asked to describe important tasks to encourage them to think, rather than just listing the first tasks that came to mind. This should have identified those most important for the frameworks. Restricting the number of responses to three per domain may have limited the number and range of tasks identified, but provided a manageable data set to evaluate the scope of the domains. By collecting data over all four SIPs, variations arising from the four different SIPs were taken into account.

The quality of data improved once the data collection took place on a form. Students provided longer statements enabling a better understanding of what they meant and they appeared to take the task more seriously.

8.4 WWO Research Execution and Results

In step 1, 344 data statements were collected for WWO – see Table 40.

8.4.1 WWO Step 2 – Preliminary data analysis

Following data entry, statements containing two or more tasks were separated out, increasing the number of data points to 374.

Breaking down statements into different components was not straight forward due to the variety of statements including:

- brief statements covering just one component
- partial descriptions covering multiple components in a variety of combinations e.g. an action verb and context, a direct object and a behaviour
- descriptions that were too vague or ambiguous to understand

The variety in statements was expected having analysed exploratory data from C47. The decision was taken not to impose a format on student statements for three reasons. Firstly, the information itself, rather that the format of the information, was more important. Secondly, from experience of data collection with C47, making data collection harder or more time consuming was not popular. Thirdly, as the plan was to collect data in four SIP reviews it was important the students were not put off attending.

A comparison of statements with the WWO practice description confirmed strong alignment. However, around 37% of descriptions were about other domain tasks (mostly MP) 'done together' as opposed to tasks about 'working with each other'. This was probably because working in a partnership was such a dominant feature of a SIP that students found it difficult to separate the two. It could also indicate that a better name for the domain than 'work with others' is required to highlight that this is about the relationship rather than the work.

Statements that just described a task from another domain, with no reference to it being done with another person, were separated from the WWO data set to be coded. This reduced the data set from 374 to 270.

The other domain tasks were analysed to identify which SIP domain or process-stage they associated with, to explore the overlaps. The results are shown in Figure 38.

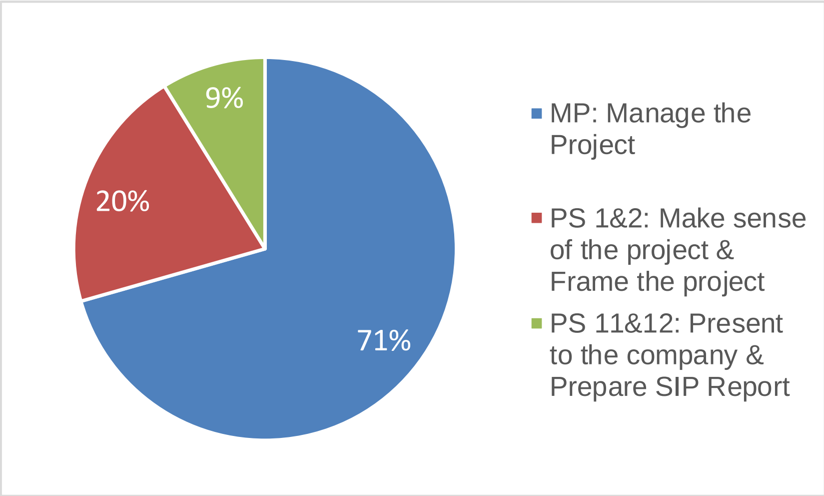


Figure 38: WWO Overlaps

The results demonstrate that 71% of the overlaps are associated with MP tasks with the remainder distributed between tasks at the beginning and end of the process-stages. These are all aspects of a SIP that are typically done together and as such this confirms the view articulated earlier that students think WWO was about doing tasks together as well as the relationship with the partner and communication.

8.4.2 WWO Step 3 – Developing the coding framework

The direct objects were selected and analysed letting categories emerge from the data combined with employing a constant comparison method to refine and challenge the categorisation. After a number of iterations the main categories of 'communication' and 'partnership' and three levels of sub-categories, SC1 to SC3, emerged. So four levels of categorisation were required to code all the answers. This categorisation was reviewed with the academic and, following a few minor revisions, was agreed to be appropriate for coding.

8.4.3 WWO Step 4 – Coding the data

Whilst coding each statement, new sub-categories emerged as some direct objects were mentioned in other components of a statement e.g. context and therefore had not been included in the analysis. This resulted in the coding framework being refined. The final WWO framework is shown in two parts: Communication in Table 41, and Partnership in Table 42, with the number of responses linking to each item.

A5 and A6 were included to capture frequently cited aspects of context – i.e. who they were working with, and stated objectives associated with the communication. The A5 results show that the students did not mention communicating with their ISMM tutor, but did mention communicating with their partner just over twice as many times as communicating with people in the company. This further reinforces the practice description of the WWO domain. In terms of A6 three categories of communication objectives emerged.

	Main Category	No.	SC 1	Sub-category 1	No.	SC 2	Sub-category 2	No.	SC 3	Sub-category 3	No.
A	Communication	27									
			A1	Mechanism	0						
	(communicate & listen)					a	communication plan	2			
						c	meetings	0			
									1	set up	1
									2	hold	1
						d	interviews	1			
						e	format	0			
									1	picture	3
						f	discussions	4			
						g	questions	1			
			A2	Content	0						
						a	ideas	7			
						b	information	5			
						c	issues / problems	9			
						d	opinions	2			
						e	findings	6			
						f	recommendations / thinking	1			
						g	expectations	1			
						h	feedback	3			
			A3	Verbal	1						
				Objective: to be 'clear and concise'		a	terms and phrases	1			
						b	structure	0			
									1	reasoning/logic	1
						c	fluency	1			
			A4	Non-verbal	0						
						a	body language	1			
			A5	With who	3						
				This is about the context of a task		a	company people	8			
									1	supervisor	2
									2	factory worker	2
						b	ISMM Tutor	0			
						c	partner	25			
			A6	Objectives							
				These are about the goal of a task		a	understand situation	8		person, company, problem, progress	
						b	common/ agreed understanding	8		situation, goals, problem, plans	
						c	test ideas and proposals	3			

Table 41: WWO Communication Coding Framework with No. of responses

Main Category		No.	SC 1	Sub-category 1	No.	SC 2	Sub-category 2	No.	SC 3	Sub-category 3	No.
B	Partnership	6									
			B1		2						
				Way of working		a	pace	4			
						b	approach	3			
									1	style	2
						c	review	4			
									1	partners ideas and analysis	9
						d	pattern	2			
									1	schedules	1
									2	work and 'private' life	1
									3	effort	1
									4	mix delegate and be together	2
						e	resolve disputes	2			
			B2	team	0						
						a	goals / objectives	2			
						b	performance	1			
						d	leadership	2			
			B3	tasks	3						
				B3b often done according to strengths or skills. Linked to B4		b	allocation / split	24			
									1	balance	2
						c	task capability requirements	1			
			B4	capabilities	2						
						a	strengths and weaknesses	9			
						b	skills	1			
									1	new skills	2
									2	existing	3
						c	confidence	1			
			B5	relationship	5						
						a	empathy	8			
						b	understanding of partner	6			
									1	personality	1
									2	motivation	3
									3	background	1
									4	culture	3
									5	needs	1
									6	goals / objectives	5
						c	agreed positions	2			
						d	partnership attitude				
									1	care	1
									2	coach	1
									3	motivate	7

Table 42: WWO Partnership Coding Framework with No. of responses

In coding the partnership data, the task allocation between partners (B3b) was the most cited item. In the associated statements, a clear link emerged with the capability sub-category B4 as the task allocations were often done according to strengths and weaknesses of the team members.

19% of statements across all WWO categories referred to behaviours. These were coded separately to generate a list of WWO behaviours – see Table 43. The number of statements mentioning each behaviour is captured which demonstrates that trust emerged as the most important.

	WWO Behaviours	No. of mentions
1	trust	11
2	patience	6
3	team orientation	6
4	be professional	5
5	open	5
6	respect	5
7	flexible	5
8	care & consideration	5
9	open minded	4
10	cooperative	4
11	be consistent	3
12	friendly	3
13	honest	3
14	constructive	2
15	responsive	2
16	tolerance	1

Table 43: WWO Behaviours

8.4.4 WWO Step 5 – Identifying the tasks

The action verbs were collated by coded item in the framework. For each coded item with multiple action verbs, the list of verbs was examined for differences to identify multiple tasks associated with this code. In some cases synonym groups were found e.g. for B3b - divide, delegate, allocate. This enabled a list of tasks to be generated. A cross-check was done with the original data statements by code to confirm that the tasks identified aligned with the description in the full statements.

81 tasks were identified where an action verb and direct object could be combined. For some codes, up to three different tasks were identified. These are captured in three different columns, #1 to #3, and there is no rank order. The tasks are shown in Tables 44 and 45 overleaf.

Code	Tasks by code #1	Tasks by code #2	Tasks by code #3
A			
A1			
A1a	decide on a communication plan		
A1c			
A1c1	schedule meetings		
A1c2	hold meetings		
A1d	interview company personnel		
A1e			
A1e1	share visual respresentations		
A1f	have open discussions		
A1g	ask clear and specific questions		
A2			
A2a	express ideas	listen to ideas	combine ideas
A2b	share information		
A2c	express issues and problems	discuss issues and problems	
A2d	express opinions	support opinions	
A2e	show findings	discuss findings	
A2f	convey recommendations and thinking		
A2g	phrase expectations		
A2h	ask for feedback	give feedback	
A3			
A3a	use appropriate terms and phrases		
A3b			
A3b1	persuade using logical reasoning		
A3c	speak fluently		
A4			
A4a			
A6			
A6a	develop an understanding of the situation		
A6b	find a common/agreed perspective	check common/agreed perspective	
A6c			

Table 44: Communication Tasks

Code	Tasks by code #1	Tasks by code #2	Tasks by code #3
B	work as a partnership		
B1	discuss way of working	synchronise way of working	
B1a	reach required pace	adjust pace	
B1b	understand partners approach to work	define joint approach	
B1b1			
B1c	understand items for review	evaluate items for review	challenge items reviewed
B1c1	exchange ideas and/or analsyis	consider ideas and/or analsyis	discuss ideas and/or analsyis
B1d	coordinate work pattern		
B1d1	align work / rest schedules		
B1d2	separate time for work and private life		
B1d3	align effort		
B1d4	communicate mix of invidual vs together working		
B1e	resolve disputes		
B2			
B2a	align goals and objectives		
B2b	reflect on performance		
B2d	take the lead on agreed parts of SIP		
B3	communicate tasks to be done		
B3b	divide tasks	clarify division of tasks	
B3b1	maintain task divide and adjust if required		
B3c	manage different task capability requirements		
B4	understand partner capabilities	assess partner capabilites	
B4a	share own perceptions of strengths and weaknesses	get to know partners strengths and weaknesses	
B4b	manage skills		
B4b1	teach new skills to partner	learn new skills from partner	
B4b2	consider existing skills	get to know partners skills	
B4c	consider confidence levels associated with tasks		
B5	manage relationship	socialise together	
B5a	develop empathy	maintain empathy by adapting	
B5b	get to understand partner		
B5b1	understand personality		
B5b2	understand motivation		
B5b3	breakdown background		
B5b4	understand culture	notice cultural differences	
B5b5	understand partner needs		
B5b6	understand partner objectives		
B5c	find agreed positions	present agreed positions	
B5d			
B5d1	care for partner		
B5d2	coach partner		
B5d3	motivate both of us		

Table 45: Partnership tasks

8.5 MS Research Execution and Results

The method set out in section 8.2 was applied. In step 1 311 data statements were collected, see Table 40.

8.5.1 MS Step 2 – Preliminary data analysis

Following data entry, statements containing two or more tasks were separated out, increasing the number of data points to 353. Breaking down statements into different components faced the same challenges for WWO described in 8.4.2.

A comparison of student statements with the MS practice description in 7.1.2 indicated strong alignment but a further component, thinking tasks, needed to be added because managing how they think, was found to be an important part of MS.

8.5.2 MS Step 3 – Developing the coding framework

As for WWO, the direct objects were selected and analysed letting categories emerge from the data employing a constant comparison method to refine and challenge the categorisation. After a number of iterations, five main MS categories emerged centred on health, thinking, self, 'being professional' and 'managing my work' with sub-categories at two levels. A sixth category of 'overlaps' was identified which were all WWO domain items. Overall, three layers of categorisation were required to code all the answers, the main level e.g. health followed by two sub-category layers SC1 and SC2.

This framework was reviewed with the academic and, following a few minor revisions, was agreed as appropriate for coding.

8.5.3 MS Step 4 – Coding the data

Whilst coding each statement, some new codes emerged as found in the corresponding step with WWO. The final MS framework is shown in two parts: Health, Thinking and Self in Table 46, and 'Being professional' and 'Managing my work' in Table 47, with the number of responses linking to each individual item.

	Main Category	No.	SC1	Sub Category 1	No.	SC2	Sub Category 2	No.
A	Health	1						
			1	physical	0			
						a	sleep / rest	5
						b	nutrition	2
						c	hygiene	1
			2	mental	1			
						a	work breaks	4
						b	relax	5
						c	working hours	2
						d	stress	9
B	Thinking	1						
			1	objective	3			
			2	decisions	1			
							factors	1
			3	creativity	4			
						a	ideas	8
			4	logic	3			
						a	supporting arguments	2
						b	structure	3
			5	reflect	2			
C	Self	1						
			1	knowing me	4			
						a	strengths & weaknesses	3
						b	knowledge (& limits)	1
						c	skills	1
			2	learning about me	0			
						a	feedback	2
			3	learning	3			
						a	skills	1
						b	knowledge	2
			4	being me	7			
						a	goals	2
						b	work / life balance	5
			5	motivation	16			
						a	methods	5
			6	managing emotions	5			

Table 46: MS Coding Framework Part 1

	Main Category	No.	SC1	Sub Category 1	No.	SC2	Sub Category 2	No.
D	Being professional	8						
	This happens in the context of a particular company which will have it's own culture which students will need to adapt to		1	Etiquette	4			
						a	dress	2
						b	oral communication	2
						c	non verbal communication	1
G	Managing My Work	23						
			1	Goals/objectives	6			
			2	Plan/ schedule	14			
	There will probably be some overlaps with MP - however these were not possible to determine from the data					a	task allocation / workload	3
						b	priorities	4
						c	task durations	1
						d	milestones	3
						e	daily plan/schedule	3
			3	Organisation	6			
						a	notes	3
						b	task tracker / to do list	7
						c	at the right place at the right time	2
						d	administration	2
			4	Delivery (tasks)	15			
						a	standard / specification	3
						b	progress / ROI	13
						c	distractions	3

Table 47: MS Coding Framework Part 2

An analysis of the statements in terms category size, see Figure 39, indicates that ‘Managing my work’ was the largest main category, followed by ‘Self’, ‘Health’, ‘Thinking’ and ‘Being Professional’. There was a clear linkage between ‘Managing my work’ and the MP domain around time management tasks. It was not possible to determine from the task statements if any were more relevant to the MP domain – however as they were all collected as statements related to MS then they were assumed to related to that domain.

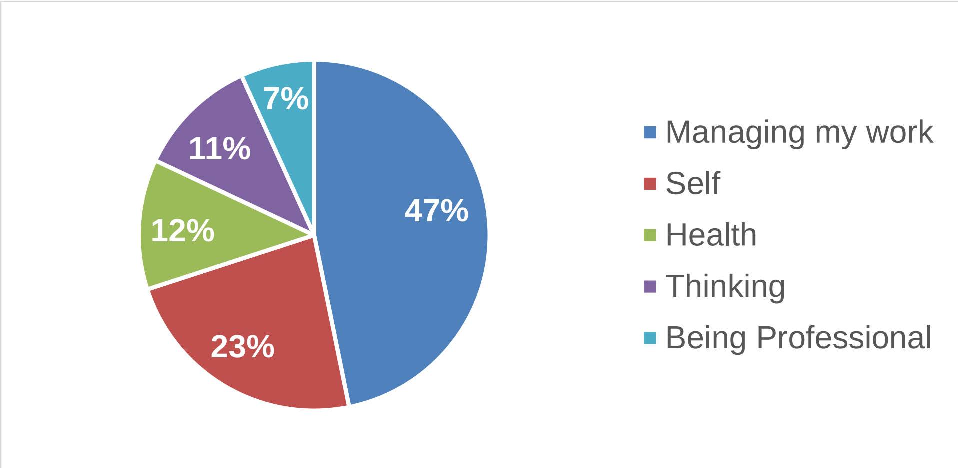


Figure 39: MS Categories by overall size

Six individual aspects accounted for 59% of the statements, see Table 48, and four came from G – 'Manage my work'. These six, taken together, highlight that SIPs are tough challenges for the students that put them under significant pressure with the major cause being managing the work within the limited time available for the SIP.

Category Score	Category Name and Code	% total	Main Category
34	Delivery (tasks) G4	13.60%	Manage my work
28	Plan/ schedule G2	11.20%	Manage my work
23	Manage my work G	9.20%	Manage my work
21	Mental A2	8.40%	Health
21	Motivation C5	8.40%	Self
20	Organisation G3	8.00%	Manage my work
		58.80%	

Table 48: MS Categories – showing six highest scoring categories

Five different 'thinking' categories emerged around being objective, creative and logical as well as making decisions and reflecting. Following a review with the academic, it was agreed that these are relevant and should be included in the domain description.

In terms of overlaps with other domains, only WWO was identified, accounting for 8% of the analysed statements. Given that many MS tasks arise in a WWO context this was not unexpected. The lower level of domain overlap compared to WWO i.e. 8% compared to 37%, would indicate that MS was more clearly defined.

19% of analysed statements referred to behaviours. These were coded separately to generate a list of sixteen MS behaviours which are shown in Table 49. The number of statements mentioning each behaviour was captured which demonstrates that focus and being open-minded emerged as the most important behaviours in this domain.

MS Behaviours	No. of mentions
focused	13
open-minded	12
patient	5
proactive	4
enthusiastic	4
efficient	4
resilient	4
realistic	4
confident	3
calm	3
polite	2
positive	2
discipline	2
responsible	2
agreeable	1

Table 49: MS Behaviours

8.5.4 MS Step 5 – Identifying the tasks

The action verbs were collated by coded item. For each coded item with multiple action verbs, the list of verbs was examined to identify it there were multiple tasks associated with this code enabling a list of tasks to be generated. A cross-check was done with the original data statements by code to confirm that the tasks identified aligned with the description in the full statements.

77 tasks were identified where both an action verb and direct object could be combined. These are shown in Tables 50 and 51. One task related to managing a specific medical condition that could have an impact on the project. Whilst this was not a generic task it has been left in the list as something students must be able to do whilst undertaking a SIP. Again up to three different tasks were identified by code so there are three different columns to capture these in.

Code	Tasks by code #1	Tasks by code # 2	Tasks by code # 3
A			
A1			
A1a	reserve time for sleep/rest	take time for sleep/rest	
A1b	refrain from drink		
A1c			
A2	keep my ADD under control		
A2a	take work breaks		
A2b	take time to relax	socialise to relax	
A2c	separate work time from private time		
A2d	manage stress		
B	standardise my thinking process		
B1	remain objective in thinking		
B2	make decisions		
B2a	understand decision factors		
B3	think creatively		
B3a	contribute ideas	consider ideas	capture ideas
B3a(cont)	rank/organise ideas	kill ideas	
B4	think logically	frame problems	
B4a	support arguments		
B4b	stucture using logic		
B5	reflect on actions	reflect on my performance	
C			
C1	understand my capabilities	capitalise on my capabilites	
C1a	recognise my strengths and weaknesses	identify SIP tasks that play to my strengths	
C1b	know my knowledge limits		
C1c	recognise my skills		
C2			
C2a	ask for feedback	receive feedback	
C3	find out how others do tasks		
C3a	improve skills		
C3b	learn new knowledge		
C4	stand up for me	speak out on my views	
C4a	decide on my goals		
C4b	set work / life balance	maintain work / life balance	
C5	stay movitated		
C5a	find ways to stay motivated		
C6	control emotions		

Table 50: Health, Thinking and Self Tasks identified

Code	Tasks by code #1	Tasks by code # 2	Tasks by code # 3
D	act professional		
D1			
D1a	adjust dress to dress code	look professional	
D1b	sound professional		
D1c	control body language		
G	manage my work		
G1	define work objectives	align with SIP objectives	influence SIP objectives
G2	develop a work plan and schedule	stick to work plan and schedule	
G2a	keep SIP workload balanced	set a realistic workload	
G2b	prioritise tasks		
G2c	set task time allocations		
G2d	create milestones	operate to milestones	
G2e	make a daily plan		
G3	organise myself	organise my work	
G3a	take notes	keep track of notes	
G3b	maintain a to do list		
G3c	be at the right place at the right time		
G3d	deal with administration tasks		
G4	complete my tasks	deliver task outputs	
G4a	decide on task standards	plan task before doing task	
G4b	review progress	manage time on task	monitor return on investment in effort
G4c	avoid distractions		

Table 51: Being professional and Managing my work tasks

8.6 Discussion

The objective was to answer the question 'What tasks contribute to a SIP?' and conduct the preliminary analysis that would support further theory development.

The question was answered from a student perspective. This was the most relevant perspective from which to understand the MS and WWO domains as only the students do these tasks and will be aware of what they do. However, the list may be incomplete because only a limited number of tasks per person were asked for.

It was clear that the tasks identified (Tables 44, 45, 50 & 51) are described at different levels of detail and do not all fit the definition of a "task" (Brannick et al., 2007) – see Table 28, used in this research. The coding frameworks contain multiple layers: four for WWO and three for MS. It is suggested that an additional level was needed for WWO as it is effectively two domains 'communication' and 'working in a partnership'. When comparing the definition of a task to the coding frameworks, WWO SC2 (sub-category 2) was considered most likely to reflect tasks and for MS, SC1 (sub-category 1). There may be variations between categories in terms of level of detail, as they emerged from data that described tasks at a wide range of detail. Within sub-categories there are sub-tasks that could be considered part of other tasks to prevent the coding frameworks becoming too extensive.

When analysing the data, it was important to examine each statement regardless of apparent level. From this analysis, clear categories of tasks have emerged and these can inform better working definitions of the domains. These categories point to specific aspects of the WWO and MS domains that can now be reviewed in the literature, to identify tasks that young professionals would be expected to do. Only subsequent to this does it make sense to refine and test a task framework.

The MS categories that emerged align with multiple, but not all, aspects of the Managing Yourself Framework shown in Figure 36. This was partly because of different perspectives, with the Managing Yourself Framework being person, rather than work centric. This framework did include thinking skills, a category that emerged from the data.

In section 7.1.2 it was argued that the tasks included in the MS domain were; those observed as part of a SIP and those undertaken in the background but essential to completing a SIP, but not the longer term personal tasks. This was reflected in the data with no one suggesting they undertook longer-term tasks.

WWO emerged as two main areas; ‘communicating with stakeholders’ and ‘working as a partnership’, which aligned well with the practice description. However, there was a significant third area accounting for 37% of responses, which aligned with tasks that were ‘done together’ but belonged to another domain or process-stage. This suggests that WWO needs a better explanation or name, or should be split into its two main areas to better signpost the nature of the tasks. The more specific definition of ‘working in a partnership’ in a host company explains the lack of fit with any of the frameworks reviewed in the literature which tended to be directed towards employees in company’s, who would be expected to work in teams.

The method employed was effective in identifying categories but the brevity and inconsistent descriptions limited the ability to identify tasks. However, sixteen key behaviours for each domain were identified. Behaviours were identified in 7.2.4 as helpful to describe how a task should typically be done in a work context. These have been reviewed with the academic and all were considered consistent with both the domain view and professional norms. Being open minded and patient were the only two common behaviours between the two groups so thirty behaviours were identified.

MS and WWO tasks are not driven by the problem-solving process. They are thus different in nature and the representation of the SIP framework, in Figure 37, captures this. From the students perspective, MS and WWO was something done throughout a SIP and these domains touched on every task they did. It was thus not surprising that there were significant levels of overlap as in practice, tasks do not happen in isolation, but in combinations as depicted in the Capability Cube Model, see Figure 9.

8.7 Conclusions

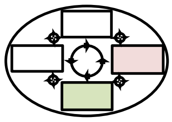
Both WWO and MS have been described in terms of tasks that students undertake resulting in a clearer understanding of these two domains. This has enabled categories of tasks to be identified and informed the definitions of these domains providing a foundation for further work.

WWO is probably best split into two domains – ‘working in a partnership’ and ‘communication with stakeholders’ and the definition of MS needs expanding to include thinking skills.

Behaviours associated with both domains have been identified from the student perspective which have been checked and found appropriate for working professionals. This list requires further testing and refinement against professional standards and literature. These will contribute to teaching students about these domains in addition to the task frameworks, as they describe professional norms.

MS and WWO domain tasks are undertaken throughout a SIP. They are sometimes difficult to differentiate due to their integrated nature and this is one explanation for why students struggle to identify these tasks from others.

CHAPTER 9: TESTING AND REFINING THROUGH-SIP DOMAINS

Chapter 9	Research Round 3	'Research design and execution' and 'problem solving' ES research activities 	This chapter focussed on answering the question 'What tasks contribute to a SIP?' for the delivery – centric Through-SIP domains of MP, MC and MI. The frameworks and tasks were tested on both students and course tutors. This resulted in refined frameworks and a list of tasks where the task descriptions require further refining for the SIP context.

9.1 Overall Research Design

A three-stage approach was adopted:

Stage 1: test the frameworks developed in Chapter 7 to determine if they cover the range of tasks students do.

Stage 2: identify the specific SIP tasks that students undertake in each domain.

Stage 3: test the frameworks and tasks on a group of experienced ISMM tutors to provide an alternative perspective.

The specific methods are discussed at the beginning of each stage.

9.2 Testing the MP, MC and MI Frameworks – Stage 1

A variance research design (Van de Ven, 2007) was selected to compare the frameworks generated in Chapter 7 with the student view of what they do in practice.

Task data was required for this comparison. In C48, MI data was collected over four SIPs and MC and MP data was collected after SIPs 3 and 4 as the PMBOK framework was mature and there was limited testing time. Since the MP framework was considerably larger than the MI framework, students were asked to describe five tasks they considered important rather than three. Table 52 summarises the data collected.

		Through SIP Domain		
	No. Students providing data	**MC**	**MP**	**MI**
SIP1	95%			93
SIP2	79%			71
SIP3	81%	133	116	91
SIP4	48%	69	65	49
Overall	**76% (Average)**	**202**	**181**	**304**

Table 52: Data captured for MC, MP and MI

The data for each domain was analysed for fit with the appropriate framework. Some did not fit because the task belonged to another domain, the response was illegible, incomprehensible or was a comment. Some reasons why students could not link their tasks to a the domain could include; not having access to the SIP Framework to refer to, not thinking in depth about their answers, or ambiguity between domain boundaries.

9.2.1 MP – Manage the project

The results are in Table 53. On average, 89% of responses related to the MP framework in Table 37 and these are mapped onto the knowledge areas in the lower part of the table. It was difficult to determine a single placement for some tasks e.g. ‘planning’ as it was unclear if students were talking about Integration Management or at a more detailed level of ‘develop schedule’ in the Time Management.

Data Analysis - fit with domain	SIP 1	SIP 2	SIP 3	SIP 4	Total	
Reponses			116	65	181	
Project Management Tasks			105	56	161	
% Project Management Tasks			91%	86%	89%	
Tasks related to other domains / process-stages			8	5	13	
Could not place			0	0	0	
Response not understandable			1	0	1	
Comments			2	3	5	
Behaviour			0	1	1	
Data Analysis – fit with framework						% Distribution
Integration Management			28	21	49	30%
Scope Management			3	2	5	3%
Time Management			52	20	72	45%
Team Management			7	8	15	9%
Communications Management			6	2	8	5%
Risk Management			3	2	5	3%
Stakeholder Management			6	1	7	4%

Table 53: MP data analysis

Time and Integration Management were the knowledge areas most often described and all descriptions could be mapped. The distribution between knowledge areas was considered appropriate given the time-limited nature of a SIP but Team Management was lower than expected which may be due to overlaps with WWO.

The Integration, Scope, Communication and Stakeholder Management categories are also in the MC domain, evaluated next.

9.2.2 MC – Manage the Client

The data analysis for MC is in Table 54. None of the relevant descriptions fell outside the MC framework in Table 38. There was an increased % of behaviours which accounted for the 77% average match with the tasks on the framework. Examples of behaviours included being considerate, professional and polite, which link to WWO.

It was again difficult to map some descriptions as they referred to two aspects of the framework. Aspects of 'Manage communications' were most often described accounting for 47% of responses. 'Integration management' accounted for 26% and 'Stakeholder management' 22%. 'Scope management' was least described but often mentioned in conjunction with Integration Management tasks. Again, all descriptions were positioned in the framework and seen to be distributed appropriately.

Data Analysis – fit with domain	SIP 1	SIP 2	SIP 3	SIP 4	Total	
Responses			133	69	202	
Client Management tasks			106	50	156	
% Client Management tasks			80%	72%	77%	
Tasks related to other domains / process-stages			8	5	13	
Could not place			0	0	0	
Response not understandable			0	0	0	
Comments			0	2	2	
Behaviours			19	12	31	
Data Analysis – fit with framework						% Distribution
Integration Management			35	5	40	26%
Scope Management			5	3	8	5%
Communnications Management			46	27	73	47%
Stakeholder Management			20	15	35	22%

Table 54: MC data analysis

It was concluded, that the MC Framework, fully fitted within MP and that MP was appropriate for a SIP as the student perspective could be fully mapped.

9.2.3 MI – Manage information

The data analysis is shown in Table 55. 91% of responses corresponded MI tasks. The remaining 9% were tasks from other domains or comments.

When analysing fit, 10% of the descriptions fell outside of the clusters described in Table 39 and were captured in a general MI cluster. On further evaluation, these tasks were found to overlap with 'Frame the problem' (process-stage 2) or 'Design the analysis' (process-stage 3). This indicated that the majority of the MI tasks only took place when process-stages 2 and 3 are complete. The remaining tasks were a good fit with the proposed framework. Tasks in the 'evaluate' category were the most frequently stated. 'Secure' data, in contrast, was mentioned once across all four projects – from the student perspective of having a backup i.e. protect information against loss. Another 'secure' data aspect, keeping client information confidential, was not mentioned. This was a definite 'should do' task but might not have been stated because students did not think this was key or challenging.

Data Analysis - fit with domain	SIP 1	SIP 2	SIP 3	SIP 4	Total	
Responses	93	71	91	49	304	
Information Tasks	78	66	86	46	277	
% Information Tasks	84%	93%	95%	94%	91%	
Tasks related to other domains / process-stages	13	4	2	3	22	
Could not place	0	0	0	0	0	
Illegible	0	0	0	0	0	
Comments	2	1	3	0	5	
Behaviours	0	0	0	0	0	
Data Analysis – fit with framework						% Distribution
Working With and Manage Information	5	7	12	3	27	10%
Retrieve Information	10	16	15	9	50	18%
Evaluate Information	26	19	17	10	72	26%
Organise Information	15	8	17	12	52	19%
Collaborate around Information	6	4	3	1	14	5%
Analyse Information	11	8	14	9	42	15%
Present Information	5	3	8	1	17	6%
Secure Information	0	1	0	1	2	1%

Table 55: MI data analysis

It was concluded that this framework was good fit with a SIP and there were strong links with a number of process-stages.

9.2.4 Discussion Stage 1

Table 56 shows a lower % match of MC tasks. The main reason was students describing behaviours (15%) rather than tasks and once these were separated out, the % match aligned, at around 90%, across all three domains. This gives confidence that the domains are interpreted reasonably consistently.

Through-SIP Domains	% Match	% Match (No behaviour)
MC	77	91
MP	89	0
MI	91	0

Table 56: % Match of responses with domains

The three frameworks appear to be appropriate but inter-domain overlaps remain a challenge and a clearer articulation of domain descriptions may be required.

Data analysis has enabled those tasks considered most important to the students to be identified. It has also highlighted that some tasks, such as keeping client data confidential and project risk management do not feature in what students consider to be important. It will be worth ensuring that such tasks and the reasons for doing them are clearly articulated to future student cohorts.

9.3 Identifying the tasks in the frameworks – Stage 2

The objective for this stage was to identify the tasks for each framework. This testing took place with C49. There were 35 students in this cohort and 17 SIPs in each of the four rounds, making a total of 68 in the year. As there was an odd number of students, there was a group of three students for one SIP in each round.

Research Design

A variance research design (Van de Ven, 2007) was selected to compare the through-SIP frameworks confirmed in 9.2 with both the student and tutor view of what tasks took place in practice. The number of through-SIP frameworks reduced to two as MC and MP were fully combined under MP.

The strategy of data collection in SIP reviews was selected for the reasons described earlier in section 8.3.

These two frameworks are at different levels of complexity and maturity and this impacted on the order and way they were tested. MI was the simplest and was judged to be the one students could most easily relate to from their prior education so was tested first so MP, a mature but complex practice framework, was tested second.

9.3.1 MI – Manage information

This testing happened in the SIP1 review when some students were still adjusting to working in English. To increase the reliability of the results students worked in their project pairs to determine a collective and negotiated view. The data collection method was designed to surface variances between the student view and the framework. An overview of the MI framework was presented as an introduction to the research activity as the class had just been working on a different topic. A detailed explanation was not provided as this could have influenced the results.

Of the 17 Induction SIPs, students involved in 16 were present, with both members being present for 12. Each SIP team was given a two-page form. On page one they were asked to describe up to 10 different MI tasks undertaken in their SIP. They were then asked to connect their descriptions to the MI framework given on page 2 and record how easy this was to do by selecting one of three options: this task was easy to fit with the framework, this task was difficult to fit in this framework, this task does not fit in this framework. Their final activity was to suggest changes to the task descriptions that would improve the framework.

The results are in Table 57. 11 teams described 10 tasks and 5 teams 8 or 9 tasks making an overall data set of 153 tasks. 8.5% were difficult to place or did not fit so are considered variances. No teams undertook the final activity. On asking them if they had comments when collecting the forms they all said the framework was clear and they had no suggestions – it was the end of the morning and lunch beckoned!

SIP1 Ref	No. tasks described	Tasks difficult to place	Tasks that did not fit
1	9	0	0
2	10	0	0
3	10	0	0
4	8	0	0
5	No data from this SIP		
6	10	0	1
7	9	2	0
8	10	0	0
9	10	2	0
10	10	0	0
11	9	1	0
12	10	0	0
13	10	1	1
14	8	0	0
15	10	1	1
16	10	2	0
17	10	0	0
TOTAL	153	10	3
% Total	100.00%	6.50%	2.00%

Table 57: Variance identificaton by SIP

The variances were discussed with the academic and further action agreed. Three tasks fell into the 'did not fit' category:

- "Determine the usage of each stream of information" – this was considered to fit into the 'evaluate relevance' or 'analyse information' tasks. It was agreed this was not specifically mentioned and that some task descriptions may need expansion and/or better alignment with SIP practice.

- “Gather feedback early from the company” - it was agreed that this might fall into 'evaluate relevance' if the students were dealing with information or it might be part of MC if they were checking understanding on something that they had generated. This indicates that students might not have a clear understanding of ‘information’ and how that differs from something they generate as part of a SIP.
- “discussing progress with the stakeholder” - was considered part of MC.

There were 10 tasks that students found difficult to place. Six were due to overlaps between frameworks:

- two with ‘framing the problem’,
- two with ‘designing the analysis’
- one with ‘gather the data’ – all process-stages where a close connection has been previously identified
- one with ‘collaborate around information’

Of the remaining responses, two were judged to be appropriately placed, one dealt with very context specific information and one picked up the point discussed earlier about students not differentiating between a SIP output and information.

It was concluded, that the overall framework proved to be robust with this cohort of students and that in 91.5% of cases the detailed task descriptions aligned with the student perspective. As a result, 7 task clusters and 15 tasks were confirmed. Further work was identified as;

- review the overlaps with the process-stages to determine how the frameworks are connected and how this can be represented
- review the tasks to achieve a better alignment with a SIP
- review and expand some task descriptions to achieve a better understanding by the students – some descriptions were very short
- provide a clearer explanation of data, information and knowledge to enable students to differentiate between them. This was one of the core principles of this framework (Avery et al., 2001)

9.3.2 MP – Manage the project

In adapting the PMBOK framework for a SIP, undertaken in Chapter 7, a subset of 7 task clusters were identified with the academic, which when tested (see section 9.2.1) aligned with the tasks undertaken by the students. Whilst this indicated that the PMBOK framework was relevant for a SIP it did not test what tasks were undertaken.

The research objectives were to determine what tasks descriptions the students thought they understood, what tasks were done by the students, and what level of description it was helpful to have in the framework when undertaking a SIP. This would inform the ongoing development of a MP SIP framework and the teaching required to help students to understand and apply it. Three questions were developed to achieve the research objectives.

1. Do the names given to the tasks in the framework make sense?
2. Which of the 47 tasks are done?
3. In what format would it be better to present the framework?

The data collection method was designed to be time efficient and to show variances between the student view and the current adaptation of the framework. This framework was considered too large to be tested in the same way as MI so a multi-step data collection strategy was developed involving four activities.

This session was scheduled on the final morning of term and only 24 of a possible 35 students attended. The research activities were done first. Before collecting any data a brief overview of the PMBOK framework was provided and the reasons why it was thought that only a subset of task clusters and tasks were relevant for SIPs.

Each student was handed a set of data collection sheets after an explanation of what questions were being addressed and why – see Appendix 3. 23 students, 66% of the cohort or 96% of those present, submitted completed sheets.

Activity 1. This was designed to answer the question ‘Do the task cluster and task names make sense?’ Students were given the existing MP framework and asked to underline any tasks that they would not be able to explain instantly. This question assumed that the task was understood if the student felt confident they could instantly describe what this meant in practice.

The results are presented in Table 58 – Activity 1 columns. The Risk Management group was least understood attracting 36.8% of responses followed by Integration Management with 19.3% of responses.

PMBOK Framework Reference Numbers and Descriptions		Activity 1 Results Tasks not able to explain		Activity 2 Results Did not do this task	
		No.	% of total	No.	% of total
1	**Integration Management**	**11**	**19.3**	**16**	**13.4**
1.1	Develop project charter	2	3.5	7	5.9
1.2	Develop project management plan	1	1.8	1	0.8
1.3	Direct and Manage Project Work	1	1.8	1	0.8
1.4	Monitor and Control Project Work				
1.5	Perform Integrated Change Control	7	12.3	4	3.4
1.6	Close Project or Phase			3	2.5
2	**Scope Management**	**4**	**7**	**9**	**7.6**
2.1	Plan Scope Management	2	3.5	3	2.5
2.2	Collect Requirements	1	1.8		
2.3	Define Scope				
2.4	Create Work Breakdown Structure	1	1.8	3	2.5
2.5	Validate Scope			2	1.7
2.6	Control Scope			1	0.8
3	**Time Management**	**2**	**3.5**	**3**	**2.5**
3.1	Plan Schedule Management				
3.2	Define Activities				
3.3	Sequence Activities				
3.4	Estimate Activity Resources			2	1.7
3.5	Estimate Activity Durations	1	1.8		
3.6	Develop Schedule				
3.7	Control Schedule	1	1.8	1	0.8
6	**Team Management**	**8**	**14**	**11**	**9.2**
6.1	Assess project team capability	2	3.5	5	4.2
6.3	Develop Project Team	2	3.5	4	3.4
6.4	Manage Project Team	4	7	2	1.7
7	**Communications Management**	**4**	**7**	**11**	**9.2**
7.1	Plan Communications Management	1	1.8	6	5
7.2	Manage Communications	3	5.3	5	4.2
8	**Risk Management**	**21**	**36.8**	**53**	**44.5**
8.1	Plan Risk Management	6	10.5	10	8.4
8.2	Identify Risks	5	8.8	9	7.6
8.3	Perform Qualitative Risk Analysis	3	5.3	10	8.4
8.5	Plan Risk Responses	4	7	13	10.9
8.6	Control Risks	3	5.3	11	9.2
10	**Stakeholder Management**	**7**	**12.3**	**16**	**13.4**
10.1	Identify Stakeholders	1	1.8	2	1.7
10.2	Plan Stakeholder Management	1	1.8	4	3.4
10.3	Manage Stakeholder Engagement	2	3.5	1	0.8
10.4	Control Stakeholder Engagement	3	5.3	9	7.6

Table 58: Tasks students could not instantly explain and those they did not do.

There were five individual tasks, that four or more students (17% of the respondents) could not instantly explain and three were from the Risk Management cluster.

The distribution of the number of tasks that individual students could not instantly explain is shown in Figure 40 where the mean = 2.5, mode = 0, median = 2. This was the student view and as this was not tested, it is probably optimistic.

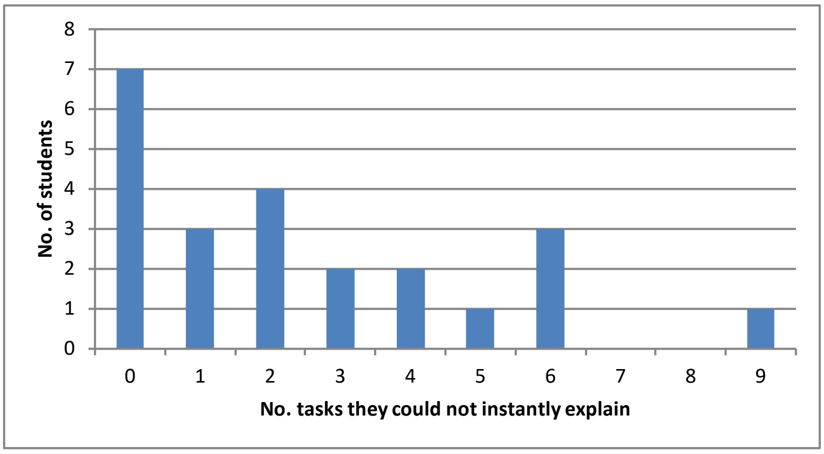


Figure 40: Distribution of tasks they could not explain

On average, each student could not explain 2 or 3 tasks, and these varied involving 23 of the 33 tested. Thus, a further level of explanation should be helpful to improve the consistency of understanding.

Activities 2 and 3 were designed to test which of the 47 tasks in the PMBOK framework were undertaken. Activity 2 tested the 33 in the proposed MP framework and Activity 3 tested the 14 that were removed in Chapter 7 to adapt it for a SIP.

Activity 2 - students were given a list of the 33 tasks and asked to underline those they did not do. The results are in the final two columns of Table 58. Risk Management was least done, 44.5% responses, and included the top five tasks not done. All tasks were done by someone, so all 33 tasks should stay.

Activity 3 - students were given a list of the 14 tasks and asked to tick a box if they had done it, and provide a comment on the context. The comment was to help identify if their understanding of this task matched those of the researcher. Of the fifteen students who identified tasks, ten provided comments and five did not. The results are in Table 59 with the right hand column containing the resulting reinstate decision negotiated with the academic following a review of the evidence.

Ref No.	Task Clusters with the 14 tasks removed from SIP PMBOK framework	No. of students who reported doing this task	Group Total	Reinstate task conclusion
4	**Cost Management**		14	No
4.1	Plan Cost Management	1		No
4.2	Estimate Costs	8		
4.3	Determine Budget	4		
4.4	Control Cost	1		
5	**Quality Management**		16	Yes
5.1	Plan Quality Management	4		Yes
5.2	Perform Quality Assurance	6		
5.3	Control Quality	6		
6	**Team Management**		4	n/a Already in SIP framework
6.2	Acquire Project Team	4		No
7	**Communications Management**		8	n/a Already in SIP Framework
7.3	Control Communications	8		Yes
8	**Risk Management**		5	n/a Already in SIP Framework
8.4	Perform Quantitative Risk Analysis	5		No
9	**Procurement Management**		5	No
9.1	Plan Procurement Management	5		No
9.2	Conduct Procurements			
9.3	Control Procurements			
9.4	Close Procurements			
	Total	52	52	

Table 59: Review of the 14 tasks eliminated from the PMBOK during initial framework construction

58% of responses related to seven tasks in Cost and Quality Management. In the PMBOK, Cost Management relates to projects with an approved budget. SIPs do not involve managing a budget but students do undertake cost estimation as part of developing a business case in process-stage 9. In the student comments, they described managing their personal expenses or developing a business case. It was concluded that this task cluster should not be reinstated and that managing personal expenses should be considered part of MS.

Quality Management is described in the PMBOK as relating to the ‘performing organisation’. For a SIP, this was the student team. Given the student comments it was agreed that the tasks were appropriate and the whole category should be reinstated.

One further task was reinstated ‘7.3 Control communications’ as there was sufficient evidence that this was undertaken.

Those not reinstated were

- 6.2 Acquire project team - as SIP teams are allocated
- 8.4 Perform Quantitative Risk Analysis - as no evidence was provided that this happened and the associated student comments suggested that they did not understand what this task entailed
- 9.1 Plan procurement management - the comments described identifying potential suppliers to determine costs and check feasibility of ideas. These fit into process-stages 8 and 9.

In summary, the findings from the above indicate that both 'Quality Management' and '7.3 Control Communications' should be reinstated resulting in an overall MP framework of 8 task clusters and 37 tasks.

Activity 4 This was a vote. Two framework options with different levels of explanation were shown and students were asked chose the framework with the preferred level of detail. Option one listed the names of the task clusters and their associated tasks whilst option two provided a one or two sentence description of each task cluster and task.

Twenty students voted: 5 for option 1 and 15 for option 2 showing a clear preference for a more detailed framework. This aligns with the recommendation from Activity 1.

In summary, 37/47 tasks in the PMBOK were done by students, but a lack of understanding of some tasks was found. This highlighted the need for more explanation, which aligned with the students' preference for a MP framework containing task descriptions as well as task names. In terms of research, further work is required on the overlaps between domains.

9.3.3 Discussion – Stage 2

Not all students were present in the review sessions resulting in participation rates of 80% for the review of MI and 66% for the review of MP.

The methods successfully identified variances between the frameworks and the student view of what they did. There is no guarantee that all potential variances were uncovered as each SIP was different and not all students were present. Some forms were not fully completed – for MI it was the last section on suggested improvements and for MP in Activity 3, students did not describe the context associated with the task in 5 out of 15 occurrences.

The method of ‘underlining tasks they could not instantly explain’ was only likely to provide an indicator. This was student self-assessment and no testing was done to verify how accurate this was.

There was evidence to suggest that providing a clearer explanation of data, information and knowledge would be helpful for students apply the MI framework.

For both frameworks it was determined that further description of the task clusters and tasks would be helpful to promote understanding.

9.4 Testing with the Tutors – Stage 3

The frameworks were tested on project tutors to provide a further perspective. Six of the nine established tutors were interviewed. Interviews were planned after SIP4 when evidence from student testing was available.

A semi-structured interview research method was selected as this would enable the frameworks to be systematically reviewed and new perspectives to be explored. The question set developed for the interviews is in Figure 41.

Through-SIP Domains: Tutors - Questions and prompts
The purpose of these interviews is to determine the tutor perspective on the proposed MP and MI Frameworks.
For each framework
Do you recognise the tasks listed as being those undertaken by students during their SIP?
What tasks might be missing from your perspective?
Do the tasks described make sense to you?
Are there any terms in this framework that are unclear or ambiguous?
Can you say something about the structure of this framework?
Does it make sense to you?
Is there anything strange, unexpected or missing?

Figure 41. Questions for ISMM tutors

Each tutor was sent a briefing note, a copy of the frameworks and the interview questions. Two interviews were done by video call and the remaining face to face over a period of 3 days from 25th to 27th March 2015. The interviews lasted around 30 minutes, notes were taken by hand and written up shortly afterwards whilst the interview was still fresh in the mind. The responses are now summarised by domain.

MP: This framework received the most comments which are summarised in Table 60. Five of the six tutors went through the framework line by line and their view on each task cluster and task was recorded and collated.

	Task Clusters and tasks	Tutor Comments on framework – only comments relating to variances or importance of the clusters/tasks captured
A	**Integration Management**	Generally only done informally at a top level
A.1	Develop project charter	Three tutors emphasised that this is done by them and not the students in creating the 'project brief' in collaboration with the company
A.2	Develop project management plan	
A.3	Direct and Manage Project Work	
A.4	Monitor and Control Project Work	
A.5	Perform Integrated Change Control	Four tutors said that this only happens occasionally when company wants something significantly different to that in the brief.
A.6	Close Project	Two tutors said that from a tutor and client perspective the project is closed when then send they send the final report. For the students the project is closed when they submit their corrected SIP report to their Tutor.
B	**Scope Management**	Two tutors commented that scope management activities do depend on how well the project has been pre-defined between tutor and company and in particular whether deliverables have been defined. One tutor commented that this was more relevant to big projects than SIPs. Two tutors thought this cluster was only done informally.
B.1	Plan Scope Management	Not required for a small project
B.2	Collect Requirements	
B.3	Define Scope	
B.4	Create WBS	
B.5	Validate Scope	
B.6	Control Scope	
C	**Time Management**	Seen by one tutor as the biggest problem area during a SIP because they spend too long on particular activities and then run out of time.
C.1	Plan Schedule Management	Only some do this
C.2	Define Activities	
C.3	Sequence Activities	
C.4	Estimate Activity Resources	One tutor stated that essential 'physical' resources are pre-sorted by Cambridge tutor e.g. desk, computer access etc.
C.5	Estimate Activity Durations	One tutor did not think the students did this One tutor commented that they do not plan (or even consider possibly?) the work needed by others in the company in support of their projects. This has links to risk management – it is very important to know who to get information from earlier rather than later and this is often a problem in companies.
C.6	Develop Schedule	Only done at a high level e.g. Gantt chart
C.7	Control Schedule	

D	**Quality Management**	Two tutors questioned whether the students did this at all and even if it was relevant. When evidence was relayed about how the students did this i.e. checking the quality of their team's work, then it was accepted. Two tutors recognised that they do these activities informally but said it was hard to evidence this from a tutor perspective
D.1	Plan Quality Management	One tutor - not done
D.2	Perform Quality Assurance	
D.3	Control Quality	One tutor – not done
E	**Team Management**	Done informally – would be better called partnership management
E.1	Plan Team Management	Both members of the team should be equals.
E.2	Develop Project Team	Limited due to time – they play to their strengths rather than develop weaknesses
E.3	Manage Project Team	Done informally
F	**Communications Management**	Comment 1 - the communication in the company is more important than with the tutor – in good projects they tend to touch base with their company supervisor on a daily basis – in other (less good) projects the interactions with the company supervisors are fewer and not on a regular basis. How much of this is really in their control? Comment 2 – done informally
F.1	Plan Communications Management	On comment - May be done but reactive rather than pro-active.
F.2	Manage Communications	
F.3	Control Communications	
G	**Risk Management**	Comment 1 – Has not noticed risk management being undertaken and if so only with regard to the timing (being able to finish on time). Comment 2 - They do these activities – mostly relating to availability and quality of data. Comment 3 - Not a lot of time to do this and it is not a priority. In hands of IfM tutor and company supervisor to identify a sensible project. Comment 4 – They do not do risk management – I reported that the students thought they did – then tutor changed their opinion and gave comments below.
G.1	Plan Risk Management	Not done
G.2	Identify Risks	May be for really critical things.
G.3	Perform Qualitative Risk Analysis	Ad hoc only
G.4	Plan Risk Responses	May do for really critical things
G.5	Control Risks	Not done
H	**Stakeholder Management**	Comment 1 - students do not have much time to do this – their main emphasis has to be managing the interactions with their company supervisor and also their IfM Tutor (this should be secondary to company supervisor). Comment 2 - tends to be more reactive than proactive
H.1	Identify Stakeholders	
H.2	Plan Stakeholder Management	
H.3	Manage Stakeholder Engagement	
H.4	Control Stakeholder Engagement	Comment 1 - generally not done but could be in context specific situations

Table 60: Tutor views on PM Framework

There was broad agreement that many tasks were done informally and it was difficult to comment on some tasks because they only typically met with the students once before the SIP started and twice during the SIP. Two tutors stated that Quality and

Risk Management were not done by the students. When the findings from the student perspective were relayed they changed their mind. There were multiple instances where tutor views differed in terms of what tasks contributed to a SIP and their importance.

MI: All the tasks were recognised as being undertaken by the students with one tutor commenting that the secure information tasks were less prominent. No specific points were raised.

9.4.1 Discussion – Stage 3

The frameworks prompted in depth discussions with more views expressed about MP than MI. Several tutors commented on the differences between the frameworks with MP based on a broader practice based framework and MI, on a narrower academic framework. MP was not seen as specific enough to the SIP context, so the relevance or importance of some tasks was questioned.

Broad practice based frameworks have the potential to extend student knowledge of practice but also cause confusion on requirements. Being able to clearly articulate learning outcomes is a fundamental for teaching (Biggs and Tang, 2007), so MP requirements need clarification.

There are a limited number of tasks where tutors can provide an evidence based view because they only observe, or are involved in, a minority. In MP, three tutors said they undertook task 1.1, Develop project charter, and that in SIP terms this was ‘Develop the project brief’. The majority of students also said they did 1.1, Table 58. This needs resolving.

9.5 Problem Solving

This chapter set out to provide an answer to the question ‘What tasks contribute to a SIP?’ for the MP, MC and MI domains. The three-stage process employed has determined

- that the tasks considered important by the students for MI, MC and MP do fit within the frameworks derived in Chapter 7
- MC does fit fully within the MP framework
- there are multiple overlaps between the MI and MP domains with the process-stages which correlates with the findings from the development of the GCF (Dowling and Hadgraft, 2013)

- there was full agreement about what MI tasks contributed to a SIP but some task descriptions required expansion. In addition, an improved ability to differentiate between data, information and knowledge would be beneficial for some students.
- there was not full agreement about what MP tasks contributed to a SIP. Whilst the student perspective was captured this did not match with that of the tutors. The MP practice description and framework requires review by the ISMM course leaders to agree on the scope of MP for a SIP.

The revised SIP framework suggested in Figure 37 may still need further work as there are still significant overlaps between the three domains of Do the project, MP and MI. The three domains may need to be conceptualised differently as the process-stages – all currently in the 'Do the project' domain involve both 'management' and 'doing' tasks.

There would appear to be different types of tasks beyond process-stage and through-SIP tasks with some e.g. review progress that could be considered management tasks and others e.g. secure data - a routine and important housekeeping task.

CHAPTER 10: DISCUSSION

In this chapter, the main results are reviewed by research round to discuss the level of confidence in the results and how they impact on the proposed theory statements.

In addition, two particular themes that emerged from the work focussed on describing skills: the impact of context, and the connections between the process-stages and through-SIP domains, are discussed to integrate the findings across research rounds 2 and 3. Finally, the application of the ES methodology is reviewed and compared to the strengths and challenges set out in Chapter 1.

10.1 Research Round 1

This research sought to answer three questions and each will be addressed in turn.

RQ1: What happened during the L&ES to support the development of SIP skills? A conceptual skills development framework (CSDF) was developed to enable a comparison with what happened during the L&ES, see Table 61 below.

	Teaching Activity Categories			
Aspect No.	**A: Describe skills**	**B: Create a learning environment to encourage deep learning**	**C: Provide multiple experiences relevant to practice**	**D: Support learning from experience**
1	Time dedicated to describing skills	Summative assessment linked to demonstration of skills post development	Number of different experiences	Time allocated to provide prompt feedback on each experience and prior to the next one.
2	Generalisations and practical principles associated with professional practice	Formative assessment linked to development of skills	Experiences that are relevant and authentic (Situational Knowledge)	Feedback is focussed on the tasks being taught and how performance can be improved
3	How to do things - process steps	Explanation of why the skill is important and how it is used	With a sufficient level of challenge to produce mastery level experiences	Time for student reflection on each experience prior to the next one.
4	Specific propositions about particular cases, decisions and actions	Level of student engagement with all parts of the skill development process	Facilitated to provide all with vicarious experience if mastery experience not achieved	Reflective activities enable learning with respect to developing skills

Table 61: Conceptual Skills Development Framework (CSDF)

Thirteen out of sixteen CSDF aspects were confidently recognised by the researcher but B1, C3 and C4 were not. Summative assessment (B1), although important in skills development, was known to happen post SIP1 and therefore should not have been included in the CSDF as it was not an aspect that happened during the L&ES. The remaining two aspects, C3 - mastery level of challenge and C4 - vicarious experiences are likely to have happened, but limited knowledge of the exercises prevented this from being verified independently of the academic.

Of the four categories, ‘Describe Skills’, was the most challenging for reliable data capture as the different aspects of skill description: A2-practice principles, A3-how to do things and, A4-specific cases, were scattered throughout the L&ES. Additionally, SIP skills are a complex set of professional skills and when the exploratory research was carried out, there was only a limited description making comparison difficult.

Two further aspects, not in the CSDF, were observed as the provision of a suitable physical learning environment and having complete sets of resources for each exercise. These observations were made from the perspective of an experienced teacher reflecting on the question “What might have negative impact on the students learning from the exercises?” The impact of a suitable physical learning environment on learning is widely recognised (Goodhew, 2010, Biggs and Tang, 2007) and having all the resources for time limited exercises is necessary if students are to have appropriate learning experiences. Other aspects that might be missing from both the CSDF and L&ES were identified as: the explicit establishment of a formative feedback culture, safe learning environment and specific activities that convert feedback and refection into development action plans to complete the experiential learning cycle. These observations align with the concerns raised in 3.4.4, that there is an extensive literature on D: supporting learning from experience, and selecting only four aspects in the CSDF was unlikely to represent an appropriate range of aspects.

In terms of answering RQ1: Fifteen aspects of skill development were confidently identified, 13 via a comparison with the CSDF and 2 from additional observations. A further two were considered likely to have happened making a total of seventeen. There may be more to be identified because not all aspects of the SDT were tested and D: Supporting learning from experiences was seen to be under-represented in the CSDF.

Reflecting on the four teaching categories, it is suggested that the provision of the multiple experiences C and supporting learning from them D, are directly responsible for developing skills, with categories A and B providing essential enablers. This aligns with work of Race (2010) who particularly highlights the importance of ‘doing’ and ‘feedback’ and Ambrose et al (2010) that stress the need for multiple opportunities for practice with clear goals and frequent feedback.

<u>RQ2: Can the students identify the activities in the Induction Module that have helped them to learn skills?</u>

Although sufficient space was provided, answers were typically short, two or three words, and described timetabled components e.g. lectures, visits and exercises. The way the survey questions were stated i.e. ‘aspects of the Induction Module’ as opposed to ‘activities in the Induction Module’ might have been a reason. 86% responses identified aspects that were likely to help them to learn skills. 75% were timetabled components, including the L&ES (23%), and 9% were skill development activities within timetabled components e.g. feedback.

When asked about aspects that did not help them learn skills 76% responses demonstrated an understanding of skills of which 15% were about poor skill development activities within timetable components e.g. lack of feedback. The remaining 61% responses were at the timetabled component level.

The two sets of results align and indicate that the majority of students could identify timetabled components but there was limited evidence that this extends at a more detailed level. Whilst results of 86% and 76% may appear high, it is worse than expected particularly for timetable components (75% and 61%). This is something that could impact on students developing skills i.e. if feedback or practice are not recognised as developing skills then this will limit student learning. It was noted, when observing the L&ES, that levels of engagement fell during certain parts of the exercises e.g. feedback and reflection which may be a further indicator that some students did not fully recognise the steps in skill development.

As the results to both questions and the observations of practice align, there is confidence that these results are valid and indicate that student ‘prior knowledge’ of skills and how they are developed may not sufficient. Further work is required to investigate what students understand about skills and how they are developed.

<u>RQ3: What prior experience do the students have that may have enabled them to develop SIP skills?</u>

Prior student experiences were investigated to indicate whether these could have developed SIP skills. A recent paper (Lattuca et al., 2017) identified three co-curricular experiences that positively and significantly related to interdisciplinary skills, including problem-solving, which were participation in non-engineering clubs and activities, study abroad activities and humanitarian engineering projects. Student design projects or competitions and engineering internships were only rated slightly less highly than study abroad activities and give more credence to the selection of these factors in Chapter 4 to answer RQ3 and hence the results in this research.

The results see Table 62 (repeat of Table 25) indicated that students were likely to have low levels of SIP skills prior to starting ISMM and are most likely to be lowest for solving industrial problems. The absolute accuracy of the data related to each of the eight skill indicators is somewhat questionable, as students were trying to remember whether they had done these activities and how often.

SIP skills	**Indicator 1**	**Indicator 2**	**Indicator 3**
Solving industrial problems	Industrial placements	Business plan competition	Work experience
% with no / some experience	33% / 67%	44% / 56%	4.5% / 95.4%
% with significant experience (subset of ‘some’ above)	2.3% More than 10/year in at least one of their last two years of study	7% - Significant effort in two competitions	11.4% >=3 years 7% >3 roles
Working as a team or **Planning a project**	Group Projects	Organising an event	Running a student club
% with no /some experience	0% / 100%	12% / 88%	40% / 60%
% with significant experience (subset of ‘some’ above)	9.3% More than 10/year in at least one of their last two years of study	18.6% Significant involvement in at least 2 years of study	21% Significant involvement in at least 2 years of study
Making presentations	Individual Presentations	Group Presentations	
% with no / some experience	2.3% / 97.7%	2.3% / 97.7%	
% with significant experience (subset of ‘some’ above) More than 10/year in at least one of their last two years of study	9.30%	9.30%	

Table 62: Summary of student prior experience data

Those with significant exposure, a subjective measure based on the assumption that more experience increased the likelihood that some skill development had taken place, was <10% for 6/8 indictors and around 20% for 2/8. This consistently indicates a low level of SIP skills. The three indicators considered most likely to demonstrate ‘solving industrial problems’ skills were the three lowest scores which supported the need to focus on this during the L&ES.

The other source of data about whether the L&ES does develop SIP skills, independent of the views of the L&ES academic, were the views of the researcher who observed the students undertaking the L&ES exercises. Sufficient evidence was seen that demonstrated that students had learnt from mistakes in previous exercises and therefore some development of specific SIP skills did take place, however it is not possible to quantify this.

Further reasons to support that skills development occurred are: the teaching and assessment activities in L&ES were the same so were perfectly aligned in accordance with the theory of Constructive Alignment (Biggs, 1996), and a cooperative learning environment was created (Prince, 2004) which helps students to achieve more.

The findings associated with each question are now integrated and reviewed together to determine the status of the proposed Skills Development Theory (SDT).

Multiple connections were identified between aspects of the CSDF as part of the observation of the L&ES. This reinforces the view that skill development is an interlinked system. Evidence to support the repeating cycles within this system was found, the description of SIPs built through the multiple exercises and students were seen to apply learning from one exercise in the next. It should be noted that the SIP description was deliberatively limited prior to Exercise 1 as this is used as a reference experience to describe an example of a practical problem and demonstrate the need for careful management of the problem solving process to deal with tight time deadlines.

The results related to RQ2 demonstrated a lack of ‘prior knowledge’ related to skills and their development by some students. This was one of several aspects removed from the proposed SDT in Chapter 3. This indicates that ‘prior knowledge’ should be reinstated and a review undertaken on the others in the light of these results. This reaffirms the systems view of the 3P Model (Biggs and Tang, 2007) and the integrated nature of teaching and learning (Biggs and Tang, 2007).

Some aspects of the SDT remain to be tested, particularly those that happened outside of the L&ES. The seventeen aspects identified expose the complexity of teaching skills and a systems model view is appropriate. Nothing was found that would suggest that the proposed SDT was not plausible or valid.

Overall, in Research Round 1, the lack of definition and description of SIP skills was found to be the most significant problem, which if solved, would generate the biggest impact in terms of research and practice. This is because a definition and description is required to develop ILO's and the associated assessment criteria to support teaching and learning, and testing of the SDT in relation to SIP skills cannot be undertaken unless reliable assessment mechanisms are established.

10.2 Research Round 2

Research Round 2 focussed on the definition and description of SIP skills. Following the identification of a task approach as a proven method of describing work and that defining tasks is an essential part of determining the skills required in a particular context, the research question **RQ4: What tasks contribute to a SIP?** was identified.

This question was addressed at a high level in terms of task clusters and then at a more detailed level to identify tasks. A conceptual high-level SIP framework was constructed from literature comprising seventeen task clusters; twelve process-stages and five though-SIP domains, as shown in Figure 42 below.

<table>
<tr><th colspan="2">Process Stages</th><th>Through-SIP Domains</th></tr>
<tr><td>1</td><td>Make sense of the project</td><td rowspan="12">Manage the project
Work with others
Manage the client
Manage self
Manage information</td></tr>
<tr><td>2</td><td>Frame the project</td></tr>
<tr><td>3</td><td>Design the analysis</td></tr>
<tr><td>4</td><td>Gather the data</td></tr>
<tr><td>5</td><td>Analyse the data</td></tr>
<tr><td>6</td><td>Interpret the data and define specific problem/s</td></tr>
<tr><td>7</td><td>Generate solutions</td></tr>
<tr><td>8</td><td>Evaluate solutions</td></tr>
<tr><td>9</td><td>Prepare a business case</td></tr>
<tr><td>10</td><td>Implementation (if time)</td></tr>
<tr><td>11</td><td>Present to the company</td></tr>
<tr><td>12</td><td>Prepare SIP Report</td></tr>
</table>

Figure 42: Conceptual high-level SIP framework

The seventeen task clusters in framework were tested and recognised by students and tutors. Five separate tests were undertaken using multiple methods, over 80 SIPs, giving a high degree of confidence that these clusters are valid. The only evidence against these were the four occasions when students reported that the SIP framework did not fit their project. An investigation found that they had been given specialist tasks rather than ill-structured problems. Whilst these seventeen clusters were consistently recognised there were overlaps, particularly between the through-SIP domains and the process-stages, so boundaries and relationships between clusters remained to be resolved.

Identifying the tasks associated with each cluster did enable better definition and description of the process-stage clusters. The four separate tests over 80 SIPs with students and tutors identified 64 indicative tasks that contributed to the 12 process-stages. It was recognised that some tasks were not relevant to all types of SIPs and thus the name 'indicative' tasks as the students need to determine if they are relevant. Given the multiple tests, over 80 SIPs and the focus on identifying variances, there is high degree of confidence in the process-stage results.

A comparison with the "Investigation" Process in the GCF (Dowling and Hadgraft, 2013) seen to be closest match with a SIP "problem solving" process, found that the SIP description was closely aligned but at a more detailed level as the GCF description had the equivalent of 8 process-stages and 48 indicative tasks.

Identifying the relationships and connections between clusters was difficult due to the iterative problem solving process and the finding that the through-SIP domains were different. It was determined that WWO and MS clusters appeared to be more consistently through-SIP in nature than MP, MC and MI, which were found to contain a combination of tasks that interlinked with the process stages and some that were through-SIP in nature i.e. repeated on a frequent basis.

It was concluded that the RQ4 had been answered for the process-stages but further work on the Through-SIP domains was required to refine the list of tasks and inform the ongoing development of the high-level framework.

10.3 Research Round 3

Work on **RQ4: What tasks contribute to a SIP?** continued for through-SIP domains.

In the problem formulation activity, working definitions of the through-SIP domains generated a better understanding of what these were in a SIP context. This demonstrated the common trap of interpreting a through-SIP domain on face value or through personal experience and not in the specific context of a SIP. A further issue emerged concerning the direct and indirect contribution for the MS domain, that although resolved, demonstrated that there could be a case for distinguishing between the tasks that contribute to a SIP and tasks that would contribute to a domain in the more general context of work. Another important objective was to describe the work required in terms of tasks and not the person.

For MP, MC and MI evidence-based frameworks were found, which when tested, were seen to cover the full range of tasks associated with the SIP context and provided a basis for developing SIP configured task frameworks for testing empirically. The confidence in these results is high because every task data point associated with these domains was found to fit in these frameworks and the variance research design ensured that this was done with a critical eye seeking variances as well as confirmations. These tests also confirmed that MC, as per working definition, was part of MP so this could be consolidated into one category in terms of research.

The extent of the PMBOK framework, used as a basis for MP, highlighted that the 17 task clusters identified in the high-level SIP framework were not well matched in terms of size with MP being of a similar size to the 12 stages process-stages as a whole with their 64 different tasks.

The specific SIP tasks that students undertook in each domain were identified by comparing frameworks constructed in the 'theory building' activity with practice during one SIP. The advantage of focussing on one domain at a time, was that it was possible to dig much deeper into the domain in the time available with the students, undertaking multiple tests and therefore more rigorous testing. The disadvantage was that this only reflected on what happened in one, rather than multiple SIPs. This was not considered a significant concern as through-SIP domain tasks were less likely to vary by problem type or SIP than process-stage tasks. More variances were identified per framework task using these methods than the approach for the process-stage tasks, which demonstrates the rigorous testing. This resulted in 15 MI tasks and 37 MP tasks being identified. The number of tasks per domain are a significant increase on those in the GCF (Dowling and Hadgraft, 2013) where only 4 information tasks and 10 project management were identified see Table 29. This might be because overlaps have been captured in their process phases, the definitions of the domains were different because the framework context is different i.e. employment rather than a SIP, or a more rigorous application of the task definition was applied.

The deeper thinking challenge in the research activities appeared to create doubts for some students about whether they fully understood the task because the majority wanted extended task descriptions for reference. There was also evidence that being able to clearly differentiate between data, information and knowledge would help students apply the MI framework more effectively. More variances were found with MP from the tutor perspective – the main problem appeared to be determining what students should or should not do as part of a SIP i.e. the practice definition. This needs resolving before a final list of tasks can be determined.

In summary, 37 MP and 15 MI tasks have been identified as contributing to a SIP from the student perspective and refinements to their descriptions would enable improved alignment with a SIP. Further work is required to determine what should constitute the MP domain from a tutor perspective before finalising the MP task framework.

For MS and WWO, no evidence-based frameworks were found in the literature that aligned with the SIP context. To resolve this, specific frameworks were intended to be created from student data using a grounded theory approach, involving a multi-stage process - started by collecting task data, per domain, specific to a SIP. Due to time limitations, this research did not progress beyond the systematic analysis of initial data sets. The analysis of this data, collected over all four SIPs in one academic year, enabled the different aspects of each domain to be identified and a preliminary evidence-based answer to RQ4 'What tasks contribute to a SIP?' where 77 MS tasks and 81 WWO tasks were identified. It was found that these domains were much more extensive than corresponding domains in the GCF (Dowling and Hadgraft, 2013) and that this was broad alignment with other research on engineering practice (Trevelyan, 2009a, Williams and Figueiredo, 2014).

WWO was found to divide into two broad areas, communication and working in a partnership. This aligns with the work of Trevelyan who specifically found that cooperative social relationships and a wide range of communications skills were at the heart of engineering practice (Trevelyan, 2009b, Trevelyan, 2010).

MS was found to divide into five distinct areas of Health, Thinking, Self, Being professional and Managing my work. This is significant as it clearly points to specific areas that can now be explored to identify and evaluate evidence-based literature, from which task frameworks could be generated. There are many similarities with the Managing Yourself Framework (Pedler and Boydell, 1999) presented in Figure 36 the differences being a result of the specific SIP context.

For both WWO and MS domains, 19% of the analysed responses referred to behaviours rather than tasks. This was also found in relation to MC where 15% of the responses were around behaviours. This would suggest that maintaining a purely work-centric task focus is difficult when dealing with people-orientated domains. A recent paper on empathy in engineering (Walther et al., 2017) proposed an interrelated three section model of empathy as; a teachable and learnable skill, practice orientation and way of being. This not only provides a firm basis for understanding empathy (part of WWO) but potentially points to a way of capturing multiple aspects of people centric domains.

In summary, RQ4 has been answered for all four domains but to varying levels of completion so further work is required.

10.4 Research Round 2 and 3 Integration

In terms of the theory proposed in Chapter 5, '*tasks that contribute to a SIP are those required by a novice to solve real, ill-structured problems supported by through-SIP domain tasks relating to project, team, client, self and information'* this will require refinement once the proposed further work on the through-SIP domains is undertaken.

These research rounds addressed the same question, RQ4. As the research progressed, two recurring themes emerged from the study: the impact of context, and connections between the process-stages and task domains. These are discussed further below.

10.4.1 Context

The SIP framework is ISMM specific and focussed on tasks the students do during the two weeks of a SIP. It does not capture tutor tasks such as sourcing SIP problems.

The two-week period makes time a significant feature of the SIP context. From the student perspective, this is demonstrated by time management tasks accounting for 45% of important MP tasks (see Table 53).

The two-week timeframe can be seen to;

- distort the problem solving process e.g. 'implementation' before presentation and an early focus on 'gather the data' which may not be typical of practice in industry but more typical of a consultancy project
- raise the level of challenge which can develop self-efficacy and a can-do attitude
- put significant pressure on the students as shown in Table 48
- discourage students from learning to do new things as they tend to play to their strengths

- focus their attention on completing the SIP deliverables which are designed to require the skills in Programme Spec

The impact of the two-week SIP time window will limit the extent to which this framework is directly applicable to SIPs undertaken at other HEI's. Other ways that a SIP may differ to other form of real problem-solving assignments at HEI's are the size of the project team and whether they are based at the company.

The impact of the company context on the problem being addressed is built into the process-stages. The initial process-stages include tasks that enable the specific problem and its context to be identified and there are later process tasks that seek to challenge and validate findings and assumptions.

Context would appear to have the most significant impact on the through-SIP domains MP and WWO. For WWO, both communication and partnership issues dominated probably caused by the limited time, as both are critical to completing the SIP.

On an individual task basis, context also played a major role in determining how the task should be carried out and thus the skills required. It is also a reason for not extending the description of any of the process-stage tasks beyond the level of a task.

Therefore the approach of describing skills by identifying the tasks and then enabling students to do these tasks in a range of contexts enables students to develop an understanding of the skills through a combination of description and doing.

10.4.2 Connections

Understanding and representing the connections between different aspects of doing a task was always going to be challenging – the 3D Graduate Capability Model, see Figure 9, tried to capture that doing a task required multiple capabilities applied at the same time.

As this research progressed, the representation of the high-level SIP framework evolved. At the end of Research Round 2 a layered approach was presented see Figure 43 below that attempted to demonstrate that the process-stages were iterative and were supported immediately by MC and MP layers as well as more generally supported by WWO, MS and MI.

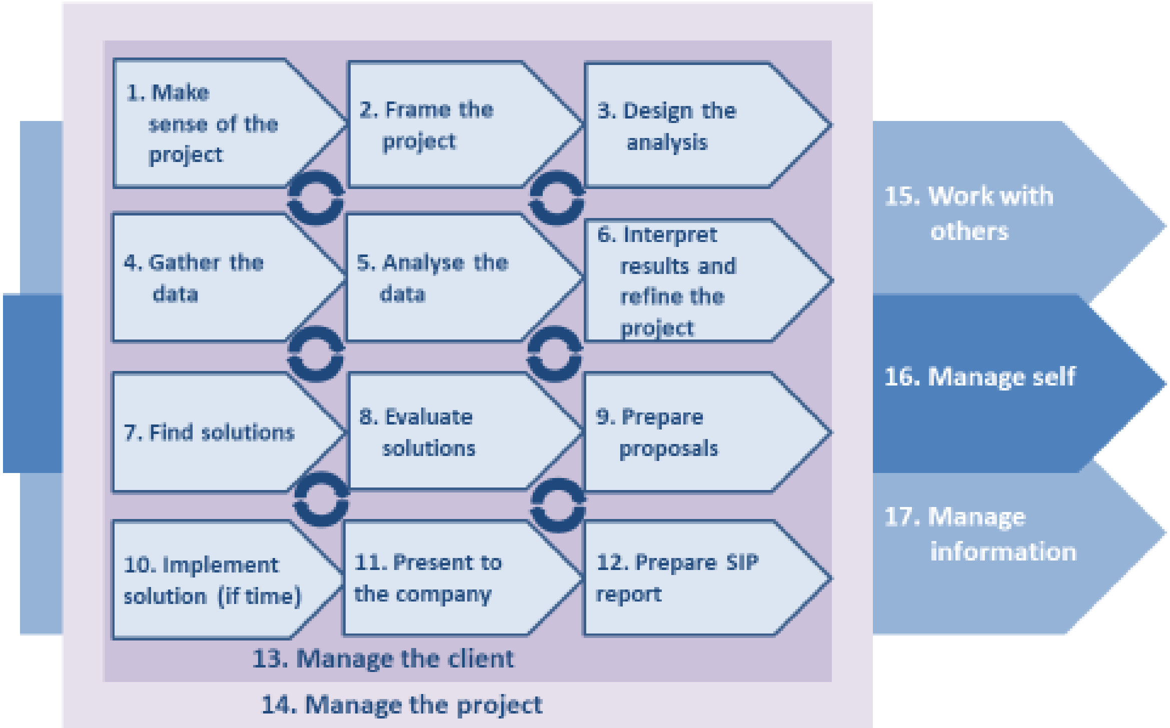


Figure 43: SIP Framework at end of Research Round 2

This was widely tested with students and tutors and seen to be a good representation. Whilst it depicted overlaps, it only differentiated between MC and MP as being more closely overlapped with the process-stages than WWO, MS and MI.

In Research Round 3, it was concluded that there were five – not seventeen – high-level categories because through-SIP domains were found to be much larger than expected. Three were delivery centric (purple themed layer) and two were people centric (blue themed layer) as shown in Figure 44 below. The twelve process-stages were represented as a new high-level domain of 'Do the project' and MI, because of its close links with 'Do the project' was included in the delivery centric layer. The interaction and overlaps between the categories was simply represented by the large circular arrow.

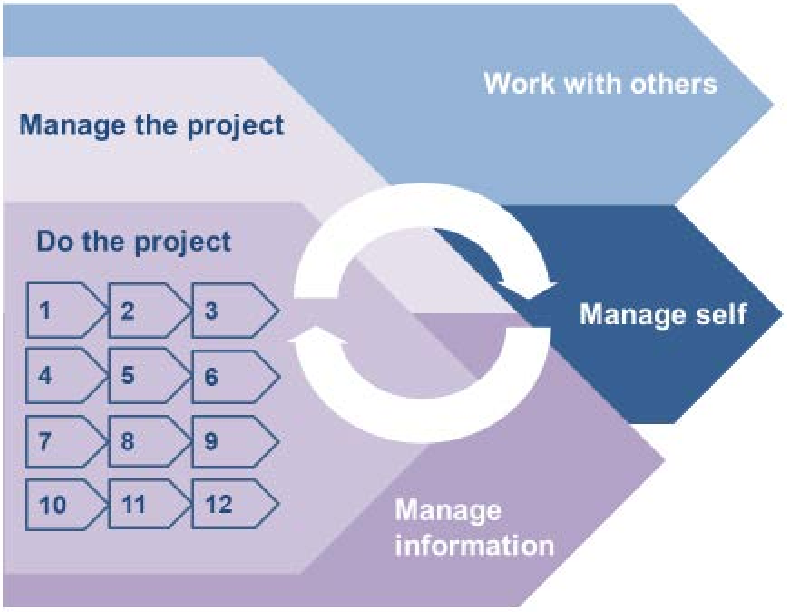


Figure 44: High-level SIP Framework mid Research Round 3.

This visual representation does not capture that tasks can be different in nature. It was found, that many tasks are process driven which aligns with the findings during the development of the GCF (Dowling and Hadgraft, 2013).

However, some tasks are also time driven, regardless of the process, and examples include deliver the presentation and submit the report. These tasks have to be undertaken whether the problem solving process is completed or not. Other time driven tasks need to be repeated on a regular basis, including management tasks e.g. review process, update plan, prioritise, communicate with stakeholders and housekeeping tasks e.g. secure data. So different through-SIP domains contain tasks with a mix of different drivers. It can be seen why a process attracts clusters of tasks as it is comprises both process and deliverable elements.

Reflecting on through-SIP domains, MI & MP are delivery centric domains containing a mix of process-stage, management and housekeeping tasks and WWO and MS are people centric domains containing a mix of management and personal management type of tasks along with some expected behaviours.

The identification of different types of tasks suggests that additional visualisations might be helpful. The delivery centric domains could be divided into ‘manage’ and ‘do’, and represented as follows, see Figure 45, resulting in four high-level categories, which all interact with each other.

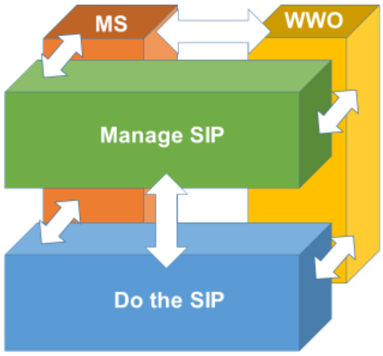


Figure 45: Potential Alternative Visualisation

If each process-stage is represented as a combination of Manage and Do tasks then this visualisation could be extended, see Figure 46, to highlight that there are both time and process driven tasks. These are tentative suggestions that represent the results to date but the further work on through-SIP domains is required to refine this work.

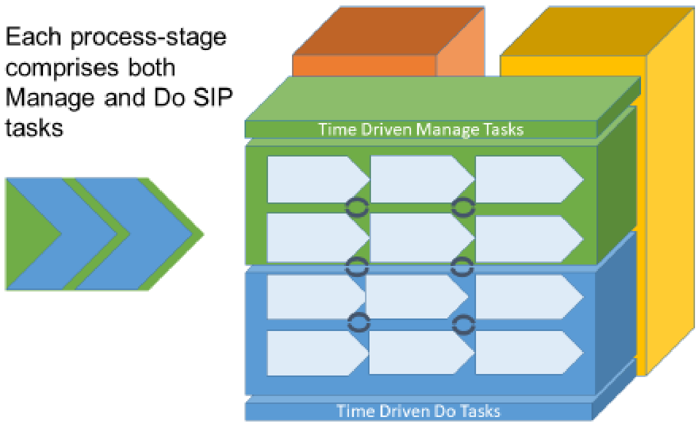


Figure 46: Expansion of Alternative Visualisation

One drawback of the framework approach is that it concentrates on the process and tasks, but does not cover their outputs or outcomes and therefore does not contain guidance on the standard of work expected and the level of skills they need to develop. A further drawback is its static appearance that does not reflect the dynamic and ongoing nature of skill development.

Throughout the research, different ways of describing skills were identified. These included written or verbal descriptions, demonstrations by tutors or students, and actually attempting to do them. The attempting to do them appeared to help the students understand the complexity of performing multiple skills at the same time.

To prepare students for SIPs, it is suggested that any important task, be it large or small, should be captured in the framework. This would mean that small housekeeping tasks e.g. secure data are captured. This reflects the advice when constructing task frameworks (Brannick et al., 2007) to report on what is important in your situation rather than get hung up on levels i.e. whether something is a task or an activity etc.

10.5 Method

An Engaged Scholarship (ES) research strategy was applied. Care was taken to realise the strengths and address the challenges of ES, see Table 63, by employing the ways suggested of achieving them where practical – see Tables 3 and 4. Of these, having 'multiple investigators' – part of C, was potentially compromised as this research was undertaken by the author in conjunction with her supervisor. To counter this, multiple perspectives were sought throughout the study from others via conferences, academic networks and publications.

Strengths of ES	**Challenges of ES**
A: Increased change that the research will be applied in practice	E: Creating and managing an effective engagement between researchers and stakeholders
B: Increases the likelihood that the research will advance knowledge for theory and practice	F: Time interacting in the study
C: Facilitate understanding of real world complex problems	G: Applying the ES method to leverage is strengths
D: Suitable for inter-disciplinary research	H: Being reflexive and objective as a researcher

Table 63: ES Strengths and Challenges - Summary

Although ES has only been applied to a small, real-world, complex practice problem, the results have helped to understand this problem and some aspects are already implemented in practice, so Strength C and Strength A have been realised at a local level. For Strength B the author is confident that knowledge has been advanced at the local level and that the emerging theoretical knowledge will be informative for the HE teaching community involved in teaching professional skills. Strength D was only tested to a limited extent as the disciplines drawn on in this research were already closely related.

For Challenge E, effective engagement with stakeholders, the most significant issue was dealing with conflicting perspectives, which happened on multiple occasions. Where differences remained after discussions, evidence was sought to resolve the situation e.g. when identifying what tasks students undertake for MP. Other conflicts of perspective were more difficult to resolve, particularly where the same terms were being used but to mean different things. These differences were often down to background and experience as different communities describe skills in a range of ways (Moon, 2004).

Challenge F, time in the study, was overcome largely by contextual factors. The co-location of the author and the programme being investigated provided easy access to the stakeholders and the five-year time horizon enabled multiple rounds of research. Having established relationships at the beginning of the study with many of the academic stakeholders was a major advantage. However, new relationships had to be developed each year with the students and some in each cohort, had limited engagement with the skill development activities that were not directly linked to assessment. Different mechanisms were tried to promote deeper levels of engagement and post SIP facilitated discussions were found to generate this.

Challenge G, applying ES, was the most challenging – like making a new recipe - it takes longer than you anticipate and sometimes the instructions only become clear during the process. Applying the methodology was greatly assisted by the detailed guidance written by Van de Ven (Van de Ven, 2007) even though some sections took multiple reads! Of the four main research activities, the 'theory building' and 'research design' were least familiar so extra care was taken to ensure a quality study. The theory building stage was the most intellectually challenging and where working as part of a larger collaborative team, more typical of an ES process, would have been helpful.

One aspect of this ES study remains a concern, albeit a small one. The L&ES followed immediately by a SIP was seen to be a miniature version of the pervasive problem of developing work skills in a HE programme. One difference between the two situations is no time gap between the L&ES and SIP1 but on completing a degree there could be a gap of several months between study and work. Although a small difference, the impact of a gap on the retention of skills is not known.

Challenge H, being a reflexive and objective researcher, was interesting. The balance between developing theory and improving practice was more difficult than dealing with conflicting data or perspectives due to the researcher being a more experienced practitioner and teacher than researcher. The questions posed by my supervisor and the detailed methodology explanations (Van de Ven, 2007) were both helpful in counteracting this.

One feature of ES is it limits how far one can plan because a full round of research activities needs to be completed to inform the following research round. The long duration of the work makes it important to be able to step out of the operational level and reflect on whether the research is still heading in the right direction and aligned with the overall aims.

The annual academic programme, with its fixed schedule of teaching and SIPs, drove the research forward as it provided hard deadlines. Whilst helpful in maintaining momentum, it also meant that some plans had to be redrawn to accommodate issues that arose and different aspects had to be prioritised. For example, the work on 'through-SIP' domains took much longer than anticipated which meant that further work planned on assessment aspects that would have enabled testing of the SDT were not able to take place. In research round 1, the timing of the L&ES meant that it could not be observed as part of the problem formulation activities. Whilst this limited the problem diagnosis using academic models and the knowledge of the exercises it did enable the research data to be collected with a fresh pair of eyes.

Applying Engaged Scholarship has been a valuable learning experience, requiring knowledge of a broad range of methods and the application of several. A greater appreciation of how theory and practice can work together has also been gained.

Overall, there is confidence that the results presented are valid and whilst the majority align with findings from other work, others particularly related to through-SIP domains differ, presenting interesting opportunities for further work.

CHAPTER 11: CONCLUSIONS

The purpose of this doctoral study was to investigate SIPs as a method of developing work skills and specifically contribute by:

- identifying how skills are developed,
- developing a theoretical description of a SIP,
- determining how this knowledge might contribute to developing work skills during HE programmes.

It was determined that SIP skills were developed via nine work relevant experiences, initially five simulated experiences in a facilitated HE environment to develop sufficient SIP skills for SIP1, followed by four differently themed SIPs, in four real companies with remote support.

A study of the initial skill development practice found that skills development was a complex process where the most significant problem was describing skills. Further investigation identified that skills can only be described at a high level, unless the task and the context associated with the task is known. Such high-level descriptions e.g. project management or team work skills are not effective in communicating the specific skills graduates need for work. SIPs were then described in terms of tasks, whilst this does not describe skills, by practising these tasks in a relevant context the required skills are developed.

This work has enabled two pervasive problems in HE to be addressed: developing work skills during a programme and describing work skills in way that enables them to be taught and learnt. In the process of doing this work, the theoretical underpinnings of a SIP have been identified and insights have been generated on the general problem of preparing students for work.

This chapter summarises the research main findings, discusses limitations and generalisations before identifying the contribution and further work.

11.1 Research Findings

Each of the four research questions are presented in turn along with a summary of the findings.

11.1.1 RQ1: What happened during the L&ES to support the development of SIP skills?

The four high level teaching activities captured in a Conceptual Skills Development Framework (CSDF) of: A - describing skills, B - creating a learning environment to encourage deep learning, C - providing multiple experiences relevant to practice and D - supporting learning from experience through feedback and reflection were found to take place during the L&ES.

Seventeen aspects of skill development were identified, fifteen via a comparison with the CSDF and two from additional observations. The seventeen aspects identified expose the complexity of teaching skills.

The many connections identified between the different aspects of skills development reinforce the view that skill development is an interlinked process and that a systems model view is an appropriate way to represent this.

The multiple experiences and associated cycles within this system were seen to develop SIP skills. Students applied learning from one exercise in subsequent ones and the different problems and contexts in the exercises, provided opportunities to extend the range of skills that could be needed in a SIP.

Of the four high-level teaching activities; A – describing skills and B - creating a learning environment to encourage deep learning – were seen to be key enablers, with C - the provision of the multiple experiences, and D - supporting learning from experiences seen as being directly responsible for developing skills.

A – describing skills, was found to be the most problematic as SIP skills were poorly defined and a consistent method of describing them to students was not employed. However, this did not prevent skills from being learnt because through the exercises students developed an understanding of what they should be doing and what ‘good’ looked like.

11.1.2 RQ2: Can the students identify the activities in the Induction Module that have helped them to learn skills?

It was found that the majority of students, approximately 80%, could identify course activities that helped them learn skills e.g. practical exercises, but there was limited evidence that they understood how they learnt from them e.g. reflection. This was worse than anticipated and a concern because it could have an impact on a students' ability to learn skills.

As a result 'Student Factors' of prior knowledge and ability, not included in the SDT should be reinstated. This reinforces the systems view of the 3P Model (Biggs and Tang, 2007) and the integrated nature of teaching and learning (Biggs and Tang, 2007).

11.1.3 RQ3: What prior experience do the students have that may have enabled them to develop SIP skills?

Of the eight experiences tested, the majority of students had some experience of undertaking group projects, making group or individual presentations, organising an event and working in a company but they had less or no experience in industrial placements, running a student club and taking part in a business plan competition. These last three were seen as stronger indicators of SIP skills.

The conclusion was drawn that students might have some SIP skills on starting the ISMM programme, but those related to solving industrial problems were limited. Therefore, the balance in the L&ES of focussing skill development on solving industrial problems was appropriate and the L&ES was the likely cause of SIP skills development.

11.1.4 RQ4: What tasks contribute to a SIP?

A high-level SIP framework has been developed that describes a SIP in terms of five different but interrelated task domains: Do the project (DP), Manage the project (MP), Manage Information (MI), Work with others (WWO) and Manage Self (MS).

The understanding of the domains developed throughout the research from an initial view of 12 process-stages and 5 through-SIP domains. The through-SIP domains were found to be larger and more complex than initially thought. They were also found to divide into two groups, with Doing the Project, Manage the Project and Manage Information being delivery centric - where tasks cluster around the problem solving process and the specified deliverables - and WWO and MS being people centric, multi-strand domains that operated throughout a SIP.

'Doing the Project' was found to comprise of twelve interconnected process-stages, which were broken down into a total of sixty-four indicative tasks that provided a more detailed description.

MP was found to contain 37 different tasks, some overlapping with the process-stages and some repeating on a regular basis throughout a SIP.

MI was found to be the smallest domain containing 15 different tasks. Again, some tasks overlapped with the process-stages and some repeated on a regular basis, of which some were related to 'house-keeping' type activities.

For MS and WWO, preliminary evidence-based frameworks and tasks were generated for the SIP context from an analysis of student data. MS task clusters emerged in five distinct areas of Health, Thinking, Self, Being Professional and Managing my Work, and WWO was found comprise of two broad areas of communication and working in a partnership. 77 MS and 81 WWO preliminary tasks were identified. Behaviours were found to be a particular feature of these people centric SIP domains.

Work on the WWO and MS domains requires extending to refine the high-level frameworks and tasks, before the key interactions with other domains can be determined. Further integration of the Doing the Project, MP and MI domains is also required to manage the overlaps between them.

RQ4: "What tasks contribute to a SIP?" has been answered and further work identified to refine and extend the results.

11.2 Limitations

This research has limitations in three main areas the associated fields of knowledge, research scope and research methodologies.

11.2.1 Fields of knowledge

The academic fields of knowledge drawn upon in this research are at different levels of development and maturity. Three particular areas of skills, professional expertise and context are conceptually weak or require further consideration. There are multiple definitions of skill see section 2.4.1, describing professional expertise and how it relates to professional knowledge remains unresolved (Young and Muller, 2014, Kotzee, 2014), and context, whilst its impact on work analysis is appreciated, has received limited consideration in research and practice (Harman, 2012). This has made contributions in these fields challenging to define and integrate.

A further difficulty of working across multiple fields of knowledge is ensuring the language is being used in the same way and sometimes this is difficult to determine.

11.2.2 Research Scope

The scope of this research limits the contexts to which the SIP Framework might specifically apply. The theoretical basis of the work should enable it, particularly the skills development teaching aspects, to be applied in multiple types of HE programmes in applied disciplines, such as Engineering, that are preparing students for practice.

SIPs are not a common practice in Engineering Education and it could be argued that certain aspects prepare students to be consultants rather than industry-based professionals. It does however teach the nature of problem solving in industry.

11.2.3 Research Methodology

In executing rigorous research, every effort was taken to apply the ES Methodology to ensure that the main criterion associated with each of the four research activities i.e. relevance, validity, truth and impact was achieved.

The research has resulted in a number of clear outcomes and enabled the identification of multiple areas that require further investigation. The unanticipated complexity that unfolded as the research on through-SIP domains progressed limited the intended outcome of this work.

Specific limitations with the different research methods employed include

- Collecting data from students – some took it more seriously than others, and for others there were second language issues which made some statements more difficult to interpret
- Students found distinguishing between behaviour and tasks difficult in the people-centric domains
- Short task descriptions did not cover the standard or depth of work considered appropriate
- The frameworks were tested using data on a limited number of important tasks. This may mean that some tasks – particularly smaller house-keeping type tasks may be missed. The multi-perspectives have helped to mitigate this on some occasions e.g. secure data but others may have been missed.

Avoiding bias can be difficult, but the variance research design and multiple perspectives taken were found to be effective in highlighting data and insights that challenged the researcher’s view.

Regardless of these methodological limitations and the scope limitations, it is deemed that this research makes useful contributions based on meaningful data.

11.3 Contribution

Three different types of contribution are identified and described below.

In addition, eight papers have been published: three journal papers and five conference papers. These are listed in the preface of this thesis.

11.3.1 Contribution to Theory

A plausible Skills Development Theory "*multiple work-relevant experiences, appropriately facilitated/taught and related to a specific set of work skills enables students to learn these skills and subsequently deploy these in practice*" related to professional work skills development during a HE programme has been proposed and tested in Chapters 3 and 4. This theory takes a heuristic model of teaching and learning in HE (Biggs, 1999) and provides a more detailed explanation of how skills, as opposed to knowledge, can be taught in practice demonstrating the complexity of skills development and the significant time and resources required. The results indicated that the theory was promising, but a method of describing skills suitable for teaching and learning was required.

It was determined that the combination of a task and the context in which it took place determines the skills required. Whilst describing tasks does not describe skills directly, it is a necessary part of identifying skills. So describing tasks and then providing students with relevant contexts to practise them – with adequate teaching support – should enable the appropriate skills to be developed.

The SIP framework describes tasks that students do during SIPs related to the process and people aspects. Having been developed theory and from student experiences during 80 different SIP's in a range of different companies there is a high degree of confidence that common SIP tasks have been identified. This framework provides an evidence-based view of a particular type of engineering practice – solving industrial problems – much of which will be relevant to others. It captures a wide range of tasks and demonstrates to engineering graduates the need to be able to undertake non-technical tasks to contribute effectively in a business environment.

11.3.2 Contribution to Knowledge

Key theories and concepts that underpin SIPs and complex skill development during a HE programme have been identified. The expertise that SIPs were intended to develop was found to align with the concept of deliberative expertise (Eraut, 1994) which he described as the essence of professional expertise. This provides an explanation as to why SIPs have been found effective in preparing student for professional practice.

Three key underpinning theories of skills development were identified as: Experiential Learning (Moon, 2004, Kolb, 1984), Constructive Alignment (Biggs, 1996) and Self-Efficacy (Bandura, 1997). Together these provided explanations why the L&ES is effective in developing skills.

This research builds on previous work to describe the skills and work required of engineering graduates and adds to the body of knowledge by investigating industrial problem solving rather than examining a particular discipline (Dowling and Hadgraft, 2013). It provides additional evidence that adopting a task approach to describing work and understanding the typical contexts that these tasks are undertaken in, would enable progress in describing work – particularly associated with 'delivery-centric' work. However, this approach was not as suitable for describing people-centric through-SIP domains. A key finding was the relative size of the people-centric or social aspects of this work which was much larger than previously reported. This adds to the limited but growing evidence that engineering practice is an intellectually challenging socio-technical activity (Trevelyan, 2014, Williams and Figueiredo, 2014).

A description of a SIP has been generated that aligns with multiple different evidence based frameworks (discussed in Chapters 5 and 7) and the views of students and tutors. This description is at three levels of detail involving a high-level SIP framework with five domains, task clusters e.g. process-stages, and associated tasks. This description is seen to capture the innovative training practice (now called a SIP) introduced over 50 years ago. This comprehensive and more detailed description of what students do during a SIP has provided a sound basis from which to review current teaching to determine improvements that can be made and identify key gaps that require filling.

Defining tasks (Chapters 5 and 6) proved to be an effective way of describing what happens in SIP process-stages such that students and tutors have a common view.

Sufficient progress has been made in defining through-SIP domain tasks (Chapters 7 to 9) to confirm that defining tasks for the delivery-centric through-SIP domains will be effective. It was determined that some through-SIP tasks are process driven and some are time driven. Whilst tasks are a component of the people-centric domains, behaviours and attitudes also featured significantly in the student data. This calls for a broader type of description for people-centric domains such as the model of empathy for engineering which includes categories of being, orientation and skills (Walther et al., 2017).

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Three key underpinning theories of skills development were identified as: Experiential Learning (Moon, 2004, Kolb, 1984), Constructive Alignment (Biggs, 1996) and Self-Efficacy (Bandura, 1997). Together these provided explanations why the L&ES is effective in developing skills.

The practice of using multiple SIPs to prepare graduates for the world of work, introduced in the 1960's, predates the main theories above. The only exception is the concept of learning through experience, where Dewey was a prominent proponent (Dewey, 1938).

11.3.3 Contribution to Practice

Multiple contributions to practice have been made in addition to the contribution of knowledge above. These have included the:

- improvement of student reflection activities, both post exercise during the L&ES and in the post SIP review sessions.
- introduction of an interactive taught session to create a common understanding of the concepts of skill and skill development delivered in the Induction Module
- the high-level SIP framework and process-stage task framework have been adopted as part of the SIP teaching and learning process. It has been used to
    - explain SIPs to the students in the ISMM Induction Module
    - help students undertaking SIPs and found to be particularly helpful in SIP1

- o inform improved summative SIP-assessment procedures
- o explain SIPs to new lecturers and tutors

The uses of the SIP framework align with Trevelyan's reasoning for why a framework would be helpful in practice (Trevelyan, 2014).

Additional contributions are anticipated on completion of the further work proposed in 11.5.

11.4 Generalisations

This section identifies how this work could contribute to the general problem of developing work skills during HE programmes.

The proposed Skills Development Theory – has the potential to become a general theory for HE. Even in its current status, the complexity of teaching skills is revealed and suggests that teaching skills is more complex than teaching knowledge. This points to the need for increased resources to be able to undertake more teaching of work skills in HE. One of the main reasons that simulated experiences are rare in HE (Goodhew, 2010, Ambrose et al., 2010) is because they are resource intensive. In addition, they require knowledge of the work context the experiences are set in, to design, develop and deliver them. So, if HE is expected to produce more work-ready graduates then more funding is required to support skill development activities. Interaction with appropriate professionals is also needed to ensure that any experiences provided are relevant and authentic.

Describing tasks and the contexts in which they apply is also a practice that could be adopted widely in the professions to help bridge the practice academic divide so that there was a common understanding of what graduates are required to do.

The SIP Framework developed would require some adjustments to apply to other real problem solving projects or placements used in HE as some aspects of an ISMM SIP including the 2 week duration, team of two and being placed in company are not common. However, it is likely that only some of the domains would require adjustments and the main categories and the relationships between them would remain the same.

11.5 Further Work

Further research work is identified on describing SIPs and developing professional work skills during HE programmes.

11.5.1 Describing SIPS

Extending the work on describing the WWO and MS domains in terms of tasks is a priority, as this will enable a wider range of SIP tasks to be described. Refinements could be made to the MP framework to develop a closer fit with the SIP context, and it is possible that MI might be absorbed as part of Doing the Project and MP.

A full task description of all the domains will inform further work on:

- the interactions between the domains and hence contribute to the development of appropriate visualisations
- the boundaries between domains enabling these to be more clearly defined

The description of SIPs by task does not cover task outputs or outcomes and therefore does not describe the standard of work expected. Further work is required to identify what these standards should be and collecting and comparing exemplars of practice at a variety of performance levels would provide an opportunity to develop a shared view.

11.5.2 Developing skills

Further work is required to investigate what students do or do not understand about skills and their development. This could be done in an informal and interactive way with students, such that students generate a common understanding of skills and their development, and tutors develop a view of that particular student cohort. A formal study could also be undertaken to develop a deeper profile of the students.

<u>Skills Development Theory</u>

Further development of the SDT model proposed (Figure 14) is required to reinstate some student factors that the research findings suggest may be significant and to test aspects not tested so far. In addition, work on describing skills can be integrated.

The SDT would then require further testing. This could be undertaken by examining other examples of skill development practice using an updated Skills Development Framework that incorporated better indicators, reflected all the aspects of an updated SDT model and in particular an increased coverage of reflection and feedback activities.

The elements of the CSDF were different in nature. Some are considered important in terms of design describing necessary components e.g. ‘experiences that are relevant and authentic', others relate to good delivery practice e.g. 'time allocated to provide prompt feedback' and others are more evaluative in nature e.g. 'level of student engagement'. Separating these different views would enable a more holistic view of the teaching perspective to be generated and potentially enable research activities to be divided into more focussed areas enabling more detailed testing.

It would also be interesting to investigate the typical number of different exercises required to become sufficiently proficient for different skills. This will depend on many factors including; the range of representative problems to be experienced prior to real-world practice, the diversity of contexts in which they happen, the complexity of the work involved, the level of resource available and the abilities of the students.

APPENDIX 1. START QUESTIONNAIRE

Dear ISMM student

One of the outcomes of the ISMM programme is the development of a wide range of skills required by young professionals to operate successfully in an industrial company. Such skills are developed through the wide range of experiences which form part of ISMM.

At Institute for Manufacturing (IfM) we are undertaking some research to obtain a more in depth understanding of skill development during ISMM and how it relates to the different types of experiences in the programme. This will enable us to refine our teaching methods, further improve the development of these skills and provide our students with better feedback on their progress.

During your Induction Module there will be a researcher (Judith Shawcross) observing some classroom activities. In addition, we need to collect some individual data. This will take the form of questionnaires at the start and end of the Induction Module and potentially subsequently during your programme. There will also be the opportunity for a small number of students to participate in interviews / focus group to reflect on preliminary findings.

We are asking you to participate in this work initially by completing the following questionnaire which should take around 20 minutes. We would like to reassure you that all individual data will be kept confidential, used only for the purposes of this research and have no impact on any formal assessment associated with the ISMM programme. The requirement for your name is to enable the data from this questionnaire to be compared with subsequent questionnaires. If you have any questions or concerns please get in touch.

****

By continuing, I agree to participate voluntarily in this study by completing questionnaires and being observed whilst participating in classroom exercises during the Induction Module. I understand the purpose of this research and the protection that will given to the information I provide. I understand that any information provided by me will remain confidential with regard to my identity and that I am not waiving any of my legal rights.

This study has been approved by the Deputy Head of Division and ISMM Programme Director. Thank you in advance for your time and effort.

Tom Ridgman and Judith Shawcross

Please print your name clearly here.

The following questionnaire will be coded so that your name

Judith Shawcross
Email: jks45@cam.ac.uk
Tel: 01223 765603

Tom Ridgman
Email: twr20@cam.ac.uk
Tel: 01223 338180

Identification Code

ISMM Induction Module - Start Questionnaire

Please read the instructions for each of the following sets of questions and consider the options before marking your answers. Please answer the questions as quickly and honestly as possible – there are no right or wrong answers.

About You

Age at last birthday	
Sex	Male / Female (Please circle only one response)

About Your Undergraduate University Education

What was your major subject/s of study?	
Which University did you attend?	
In which Country was your University located?	
What was the length of your degree course?	
In what year did you graduate?	

Please indicate how often you were involved in the following activities **as part of your course of study** for each academic year. The 1 2 3 4 in each box represent your different years of study. (Please ignore 4 if your course was only 3 years in duration) ***You will need to circle each number once on every row.***

Activity	Never	Once or twice an academic year	Several (3 - 10) times an academic year	Many times (10+) an academic year
Individual Projects	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Group Projects	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Individual Presentations	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Group Presentations	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Industrial Visits	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Group based classroom exercises or simulations	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Industrial Placements - i.e. time spent working in an industrial company	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4

Identification Code

About Your Undergraduate University Education (continued)

Please indicate how often you were involved in the following activities **as part of your extra curricula activities** whilst attending University. The 1 2 3 4 in each box represent your different years of study. (Please ignore 4 if your course was only 3 years in duration)
You will need to circle each number once on every row.

Activity	Never	Once or twice a year	Once or twice a month	Once or more a week	Once or more a day	Significant effort over a short period of time
Event organisation e.g. Student ball	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Running a student club or society	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Participate in a Business Plan or Design Competition	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4

About your work experience

Please list your work experience during your undergraduate degree or since completing your undergraduate degree

	Type of job (*tick all those that apply*)			**How closely was this work related to your undergraduate degree? (*tick one option*)**			
Job Title	Summer vacation job	Full time Employ-ment	Part time employ-ment	Closely related	To some extent related	Not related	**Duration (months)**

Please turn over

Identification Code

Background Information

About you:

What is your present nationality?	
People describe their ethnicity in a number of different ways - how would you describe yours?	
Where were you born?	
In which country / countries did you complete most of your primary education?	
In which country / countries did you complete most of your secondary / high school education?	
When did you first come to the UK?	

About your parents:

	Mother	Father
In what country were you parents born?		

Did your parents complete university? Please select from the following options (tick one box only per parent)

	Mother	Father
Did not start or did not compete university		
University undergraduate degree		
Post-graduate degree (Masters, PhD, MD)		
Not sure		

And finally.............
What are your **three** most important reasons for taking the ISMM programme?

Many thanks for completing this questionnaire. Please ensure it is returned directly to Judith Shawcross, Tom Ridgman or to the ISMM teaching office staff.

APPENDIX 2. CSF TESTING DETAILED RESULTS

This Appendix contains the detailed results associated with Chapter 6, Action Research Cycles 2 and 3.

Action Research Cycle 2 Results (ARC2)

The following colour key denotes the no. of students per task per day. Each process-stage or through-SIP domain is referred to by a number. These connect back to the CSF in Figure 39.

Results Key:

No. of students per task per day	Colour Code
0	
1 to 3	
4 to 6	
7 to 9	
10 or 11	

Process Stage	Ref No	Task	Pre	SIP Week 1							SIP Week 2					Post
				M	T	W	T	F	S	S	M	T	W	T	F	
1	1.1	Assimilating information about the company														
	1.2	Assimilating information about its markets														
	1.3	Assimilating information about its challenges														
	1.4	Dissecting a problem brief to determine areas to question														
	1.5	Defining SMART project objectives														
	1.6	Defining key indicators of success														
	1.7	Other														
2	2.1	Define problem boundaries / design scope														
	2.2	Break down problem/design into component parts														
	2.3	Developing hypotheses – one for each problem component														
	2.4	Collate customer requirements														
	2.5	Other														
3	3.1	Identify what analysis needs to be undertaken to prove / disprove each hypothesis or determine detailed customer requirements														
	3.2	Prioritise in order of significance														
	3.3	Describe the likely format of the end product of each analysis														
	3.4	Identify what data is needed – qualitative and quantitative														
	3.5	Identify sources of data														
	3.6	Other														
4	4.1	Arranging interviews / meetings														
	4.2	Conducting structured / semi structure interviews face to face														
	4.3	Undertaking telephone interviews / enquiries														
	4.4	Extracting data from company / industry / research reports														
	4.5	Extracting required data from company systems														
	4.6	Extracting data from public sources														
	4.7	Collect new data														
	4.8	Other														
5	5.1	Clear and logical analysis														
	5.2	Dealing with incomplete or inconsistent data														
	5.3	Assessing reliability/validity of data														
	5.4	Dealing with large data sets														
	5.5	Analysing qualitative data														
	5.6	Analysing quantitative data														
	5.7	Other														

Frequency pattern of tasks in ARC2 (part 1)

Process Stage	Ref No	Task	Pre	SIP Week 1							SIP Week 2					Post
				M	T	W	T	F	S	S	M	T	W	T	F	
6	6.1	Logical thinking														
	6.2	Recognise patterns or anomalies in the data														
	6.3	Draw insights from the results														
	6.4	Check the results make sense														
	6.5	Thinking from different perspectives														
	6.6	Other														
7	7.1	Identify resource and operational constraints														
	7.2	Collect ideas of potential solutions from company sources														
	7.3	Generate ideas using creative (divergent) thinking														
	7.4	Other														
8	8.1	Identify appropriate selection criteria														
	8.2	Apply a logical methodology for ranking														
	8.3	Other														
9	9.1	Develop a clear, concise, logical argument														
	9.2	Identify and quantify (where possible) benefits, risks and resource requirements														
	9.3	Develop alternative options with comparable data to enable a choice between them														
	9.4	Other														
10	10	Draw up a detailed implementation plan														
	10	Obtain agreement by appropriate people														
	10	Monitor progress of implementation and deal with issues as they arise														
	10	On completion check changes are fully operational and delivering benefits anticipated														
	11	Other														
11	11	Prepare a clear set of slides														
	11	Practice the presentation														
	11	Deliver the presentation in the time allowed														
	11	Answer questions in a professional manner														
	12	Other														
12	12	Agree structure, format and responsibilities														
	12	Prepare drafts of sections														
	12	Collate sections and edit report														
	12	Other														

Frequency pattern of tasks in ARC2 (part 2)

Through SIP	Ref No	Task	Pre	SIP Week 1							SIP Week 2					Post
				M	T	W	T	F	S	S	M	T	W	T	F	
13	1	Agree communication methods, frequency, timing and who with														
	2	Communicate plans and progress concisely														
	3	Discuss and resolve issues as required														
	4	Other														
14	1	Prepare an outline project plan														
	2	Identify and understand group capabilities														
	3	Prepare detailed plans for each project stage														
	4	Set and maintain priorities														
	5	Allocate tasks between group members														
	6	Monitor progress against plan and update plans as required														
	7	Other														
15	1	Carry out agreed tasks														
	2	Work cooperatively and adapt to needs of group														
	3	Listening														
	4	Ask questions and seek clarification														
	5	Take initiative or lead when appropriate														
	6	Stand back and support when appropriate														
	7	Negotiate agreements														
	8	Provide feedback to group member														
	9	Other														
16	1	Manage time effectively														
	2	Operate to high standards														
	3	Listen actively														
	4	React to criticism constructively														
	5	Develop strategies to adapt to context														
	6	Manage stress														
	7	Others														
17	1	Use appropriate sources of information														
	2	Use appropriate systems / software														
	3	Interpret a variety of information forms														
	4	Organise information in an appropriate way for the intended audience														
	5	Other														

Frequency pattern of tasks in ARC2 (part 3)

Action Research Cycle 3 Results (ARC3)

Key for ARC3 results overleaf

No. of students per task per day	Colour Code
0	
1 to 8	
9 to 17	
18 to 25	
26 to 31	

These groups are aligned in terms of % of student responses to those in ARC2 making the results visually comparable.

Process Stage	Ref	Task	Pre	SIP Week 1							SIP Week 2					Post
	No			M	T	W	T	F	S	S	M	T	W	T	F	
1	1.1	Assimilating company information														
	1.2	Assimilating market information														
	1.3	Assimilating information about company challenges/issues														
	1.4	Dissecting a problem brief to determine areas to question														
	1.5	Discuss project brief with company and determine expectations														
	1.6	Other														
2	2.1	Define project scope and boundaries														
	2.2	Break down problem /design /investigation into component parts														
	2.3	Identify the questions / hypotheses for each component														
	2.4	Other														
3	3.1	Identify analysis tools/methods suitable to answer 2.3														
	3.2	Select most appropriate tools/methods														
	3.3	Define the required output														
	3.4	Identify what data is needed – qualitative and quantitative														
	3.5	Identify sources of data														
	3.6	Other														
4	4.1	Arranging interviews / meetings														
	4.2	Conducting structured / semi structure interviews face to face														
	4.3	Telephone interviews / enquiries														
	4.4	Extracting data from company / industry / research reports														
	4.5	Extracting data from company systems														
	4.6	Extracting data from public sources														
	4.7	Taking physical measurements														
	4.8	Designing, distributing and collating data via survey / questionnaire														
	4.9	Other														
5	5.1	Enter data														
	5.2	Dealing with incomplete or inconsistent data														
	5.3	Assessing reliability/validity of data														
	5.4	Dealing with large data sets e.g. those requiring use of macro's														
	5.5	Analysing qualitative data														
	5.6	Analysing quantitative data														
	5.7	Develop visualisations of data														
	5.8	Other														

Frequency pattern of tasks in ARC3 (part 1)

Process Stage	Ref No	Task	Pre	SIP Week 1							SIP Week 2					Post
				M	T	W	T	F	S	S	M	T	W	T	F	
6	6.1	Identify anomalies in data														
	6.2	Consider results in relation to hypotheses / questions posed in 2.3														
	6.3	Draw insights from the results														
	6.4	Validate results from different stakeholder perspectives														
	6.5	Refine project definition, boundary, scope etc. as required														
	6.6	Other														
7	7.1	Generate ideas using creative thinking														
	7.2	Collect ideas for potential solutions from company sources														
	7.3	Identify resource & operational constraints														
	7.4	Shortlist feasible solutions														
	7.5	Other														
8	8.1	Identify appropriate selection criteria														
	8.2	Test different options to generate performance data														
	8.3	Apply a logical method for ranking options														
	8.4	Identify a preferred solution														
	8.5	Other														
9	9.1	Develop supporting arguments														
	9.2	Develop implementation plan identifying key resources required														
	9.3	Develop financial business case														
	9.4	Identify and quantify (where possible) benefits, risks and resource requirements														
	9.5	Other														
10	10	Obtain agreement by appropriate people														
	10	Make agreed changes														
	10	Monitor progress of implementation and deal with issues as they arise														
	10	On completion check changes are fully operational and delivering benefits anticipated														
	11	Other														
11	11	Prepare the presentation														
	11	Practice the presentation														
	11	Identify questions and prepare answers														
	11	Deliver the presentation														
	12	Other														
12	12	Agree report structure, format and responsibilities														
	12	Prepare draft report sections														
	12	Collate sections and edit report														
	12	Other														

Frequency pattern of tasks in ARC3 (part 2)

Through SIP	Ref No	Task	Pre	SIP Week 1							SIP Week 2					Post
				M	T	W	T	F	S	S	M	T	W	T	F	
13	A.1	Agree communication methods, frequency, timing and who with														
	A.2	Confirm/rewrite project brief with client														
	A.3	Communicate plans and progress concisely														
	A.4	Discuss and resolve issues as required														
	A.5	Other														
14	B.1	Defining SMART project objectives														
	B.2	Defining key indicators of success														
	B.3	Prepare an outline project plan														
	B.4	Identify and understand group capabilities														
	B.5	Prepare detailed plans for each project stage														
	B.6	Set and maintain priorities														
	B.7	Allocate tasks between group members														
	B.8	Monitor progress against plan and update plans as required														
	B.9	Ad hoc communication with ISMM placement tutor														
	B.10	Other														
15	C.1	Take the lead														
	C.2	Stand back and support														
	C.3	Negotiate agreements														
	C.4	Provide feedback to group member														
	C.5	Other														
16	E.1	React to criticism constructively														
	E.2	Adapt actions to changing circumstances														
	E.3	Manage stress														
	E.4	Other														

Frequency pattern of tasks in ARC3 (part 3)

APPENDIX 3. DATA COLLECTION INSTRUMENTS FOR MP

This presents the initial briefing and data collection instruments used in 9.3.2. related to MP, Manage the Project. Please note that at the time of data collection, ‘Manage the Project’ was called ‘Project and Task Management’ and MC, Manage the client was called ‘Manage the relationship with the client’.

Initial Briefing Slides.

Knowledge Areas	Initiating	Planning	Executing	Monitoring & Control	Closing	TOTAL
Integration Management	1	1	1	2	1	6
Scope Management		4	1	2		6
Time Management		6		1		7
Cost Management		3		1		4
Quality Management		1	1	1		3
Human Resource Management		1	3			4
Communications Management		1	1	1		3
Risk Management		5		1		6
Procurement Management		1	1	1	1	4
Stakeholder Management	1	1	1	1		4
TOTAL	2	24	8	11	2	47

Project and Task Management – 33 Processes

Knowledge Areas	Processes
Integration Management	Develop Project Charter, Develop Project Management Plan, Direct and Manage Project Work, Monitor and Control Project Work, Perform Integrated Change Control, Close Project
Scope Management	Plan Scope Management, Collect Requirements, Define Scope, Create Work Breakdown Structure (WBS), Validate Scope, Control Scope
Time Management	Plan Schedule Management, Define Activities, Sequence Activities, Estimate Activity Resources, Estimate Activity Durations, Develop Schedule, Control Schedule
Team Management	Assess Project Team Capability, Develop Project Team, Manage Project Team
Communications Management	Plan Communications Management, Manage Communications
Risk Management	Plan Risk Management, Identify Risks, Perform Qualitative Risk Analysis, Plan Risk Responses, Control Risks
Stakeholder Management	Identify Stakeholders, Plan Stakeholder Management, Manage Stakeholder Engagement, Control Stakeholder Engagement

Adapted from PMBOK Guide

Manage the relationship with the client Sub-set of Project and Task Management

Knowledge Areas	Processes
Integration Management	Develop Project Charter Develop Project Management Plan Perform Integrated Change Control Close Project
Scope Management	Define Scope Validate Scope
Communications Management	Manage Communications
Stakeholder Management	Identify Stakeholders Manage Stakeholder Engagement

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Adapted from PMBOK Guide

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Describing the research questions.

Questions about this framework

- Do the names given to the activities in this framework make sense to you? Could you explain what they meant to a new colleague?
- Are the 33 activities we selected from the 47 in the PMBOK the activities that are done in projects?
- In what format would it be better to present this framework? *We want it to be able to help you!*

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Activity 1 Instructions

Activity 1

Looking at the labels on the framework are there any that you would not be able to instantly explain?

On an individual basis…….<u>underline any labels where you have ANY doubts about what it means</u>

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Data Collection Sheets

Activity 1 – Underline the activities that you would not be able to instantly explain?

Activity Groups	Activities
Manage the project – at top / integration level	Develop a Project Charter; develop a project management plan; direct and manage project work; monitor and control project work; perform integrated change control; close project.
Manage the scope	Plan scope management; collect requirements; define scope; create Work Breakdown Structure; validate scope; control scope
Manage the activities and schedule	Plan schedule management; define activities; sequence activities; estimate activity resources; estimate activity durations; develop schedule; control schedule
Manage the team	Assess project team capability; develop project team; manage project team
Manage communications	Plan communications management; manage communications
Manage risk	Plan risk management; identify risks; perform qualitative risk analysis; plan risk responses; control risks
Manage stakeholders	Identify stakeholders; plan stakeholder management; manage stakeholder engagement; control stakeholder engagement

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Please enter your name:

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Activity 2 – Underline the activities you **didn't** do?

Activity Groups	Activities
Manage the project – at top / integration level	Develop a Project Charter; develop a project management plan; direct and manage project work; monitor and control project work; perform integrated change control; close project.
Manage the scope	Plan scope management; collect requirements; define scope; create Work Breakdown Structure; validate scope; control scope
Manage the activities and schedule	Plan schedule management; define activities; sequence activities; estimate activity resources; estimate activity durations; develop schedule; control schedule
Manage the team	Assess project team capability; develop project team; manage project team
Manage communications	Plan communications management; manage communications
Manage risk	Plan risk management; identify risks; perform qualitative risk analysis; plan risk responses; control risks
Manage stakeholders	Identify stakeholders; plan stakeholder management; manage stakeholder engagement; control stakeholder engagement

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Activity 3 – Have you done these in either project?

Knowledge Areas	Processes	If yes tick the box and describe the context.
Cost Management	Plan cost management Estimate costs Determine budget Control costs	
Human Resource Management	Acquire project team	
Communications Management	Control Communications	
Risk Management	Perform quantitative risk analysis	
Quality Management	Plan quality management Perform quality assurance Control quality	
Project Procurement Management	Plan procurement management Conduct procurements Control procurements Close procurements	

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Activity 4 – A vote

Option 1:

Knowledge Areas	Processes
Integration Management	Develop Project Charter, Develop Project Management Plan, Direct and Manage Project Work, Monitor and Control Project Work, Perform Integrated Change Control, Close Project

Option 2:

1	Integration Management	Project Integration Management includes the processes and activities to identify, define, combine, unify and coordinate the various processes and project management activities within the five Project Management Process Groups. In the project management context, integration includes characteristics of unification, consolidation, communication and integrative actions that are crucial to controlled project completion, successfully managing stakeholder expectations, and meeting requirements.
1.1	Develop project charter	The process of developing a document that formally authorises the existence of a project and provides the project manger with the authority to apply organisation resources to project activities
1.2	Develop project management plan	The process of defining , preparing and coordinating all subsidiary plans and integrating them into a comprehensive project management plan. The project's integrated baselines and subsidiary plans may be included with the project management plan.
1.3	Direct and Manage Project Work	The process of leading and performing the work defined in the project management plan and implementing approved changes to achieve the project's objectives

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APPENDIX 4. SUPPORTING INFORMATION ABOUT ISMM

A4.1 Extract from the ISMM Student Handbook describing Industrial Projects – referred to as SIPs in this thesis.

Role of Industrial Projects.

ISMM Projects have two goals, the first is to educate the graduate and the second is to meet the project objectives. Project objectives are usually aimed at adding value to the company and producing recommendations to achieve permanent changes for the better. There are many shades of opinion in a company and a project not only has to come up with a good recommendation but also be sufficiently convincing to inspire the company to make the changes you recommend.

Thus the challenges these projects provide are amongst the most useful learning experiences on the course. Deciding which tools and techniques to apply, having to work with strangers and being able to enlist their help and trust, discovering that ideas which seemed straightforward in the classroom do not work so easily in real life and having to deliver something of value against a tight timeframe; anticipate the problems you will face in your future career.

There are three opportunities to build your confidence; in your attitudes, behaviour, persuasiveness; in your ability to inspire confidence in the people you talk to during the project: and in the quality of the presentation and final report.

There are four two-week industrial projects in all. They follow the Induction Module, the Industrial Systems Module, the Sales, Marketing and Business Strategy module and the Manufacturing Processes Module. In the case of this last one, projects will also be chosen to cover topics relevant to the Technology and Innovation Management project.

Please note that all Projects are “Commercial in Confidence” and this is a very important aspect of professional attitude and practice. For the avoidance of any doubt any ideas or foreground Intellectual Property generated during a project reverts to the company.

Selecting projects and timings.

Two weeks before the start of the project, a list will be published on what is on offer. This is in the form of a Project Brief giving a short description of the objectives to be achieved along with what is required to achieve these. A Background on the company is also provided.

You will then be given a Voting Form to nominate your preferred projects. Every effort is made to give you one of your preferences. Where that proves impossible, we will try to remedy the situation for the following project.

The reports must be handed on the Wednesday following the end of the project. These will then be read by your Supervisor who will arrange to have a Supervision with you to discuss what you have written and suggest improvements. This corrected version is then sent to the company for their comments. This can cause a delay, as the marks must take the feedback from the company into account.

Project Accommodation

If you are working on a project that is too far from Cambridge to travel to each day, you will be given accommodation nearby. Twin rooms are standard for project teams of the same gender, or if there is more than one team in a geographical area you will be booked into the same accommodation in twin rooms where possible. Breakfast should be provided, but you will be notified of alternate plans if not.

If you have a problem or concern with your accommodation, please get in touch with the Teaching Office initially. You will also be given an out of hours emergency number for the Travel Department.

Report Writing

Why the Report is Important

The report is of singular importance since industrial decision making time-scales are much longer than ISMM project periods and the impression you made at the presentation will be a distant memory when decisions come to be taken.

At this stage the report will have to stand on its own as a clear, comprehensive document that will persuade its audience to back your recommendation. Without this you will have failed to meet the project objectives.

Structure and Layout

The majority of organisations use standard document layouts. This enables managers familiar with the layout to appraise themselves of the content more quickly and therefore process a larger amount of information each day. This also results in managers being irritated if the standard layout is not followed and therefore developing negative feelings towards the work being read. To reinforce this discipline ISMM has adopted a standard layout for all reports.

Title page

The standard title page must be adopted in the words used, position, capitalisation, font and size. An example can be found on Moodle.

Executive Summary

This is the most important page in the book. Senior managers are very busy and are forced to ration the amount of attention to individual issues. A well-written summary enables the report to be approved immediately without having to examine the detail or refer back to the project sponsor. An executive summary must contain:

- a description of the problem
- the method and scope of the investigation
- the options considered
- the recommended solution

Any surprising outcomes should be explained. The summary should be less than one page but more than three quarters of a page in single line spacing.

Contents

Sheet to be set out as shown in the example on Moodle.

Acknowledgements

This section is to thank company personnel for their support. It will also be used by those assessing whether to implement the recommendations to see who was involved.

The acknowledgements should be formal in a warm, friendly manner; there is no need to overdo it and mention everyone spoken to. Some categories can be grouped together, for example, "all the operators on the No. 6 Widget Line".

Introduction

This should cover: a brief description of the Company in one or two sentences for the benefit of ISMM and the external examiner, a brief description of ISMM in one or two sentences for the benefit of the Company, a description of the problem outlined in the brief (the brief should also be included as an appendix to the report) and a short description of the methodology of the project.

Main Body

This will be specific to a particular report but should generally include a description of the approach used, analysis of the data, alternative solutions considered, the solution selection criteria and a financial justification leading to a proposed solution. The level of detail should be sufficient to support the arguments being proposed; if a large data analysis is required the detail should be put in the appendices.

Consider the structure carefully before beginning to write. A common problem is to fail to plan the report and write down a sequential diary of events. The reader is most affected by the first and last sentences in a section, the first sentence is used to decide whether to bother reading the rest of the section and the last sentence lingers longest in the memory.

Conclusions

This section draws together the threads from the main body. No new information should be introduced. It will repeat the ideas from the executive summary and from the main body of the report so it is important to try and find fresh words that re-iterate the message but do not make it sound repetitive.

Recommendations

It is often difficult to separate conclusions and recommendations. While the conclusions should argue points out of the main text, the recommendations propose a course of action for the company. They must be substantiated by the data contained in the main body of the report. They should be factual and pragmatic. Where there are too many unknowns, further investigation can be recommended. If the task looks very large it can be divided up into short, medium and long term action plans with decision points on when and whether to proceed.

Figures and Tables

These break up the text and make reports more readable, but it must be recognised that many of the readers will have a photocopy of the report, therefore colours and small differences in shading should be avoided. Wherever possible, A4 diagrams should be used because often people either can't or won't bother to copy difficult sizes and the report may be circulated with the page missing.

Proper layout of graphs and tables is essential including axis legends and titles. Embedded figures & tables should be kept short and lengthy pieces of analysis kept in appendices. Also try to limit the volume of appendices because bulky appendices limit an individual's enthusiasm to photocopy your report and therefore restrict its audience. Copies of working documents should be neatly packaged, indexed, and left with the project supervisor.

Writing Style

The language used has a large impact on the reader's acceptance of the report. Everything is written in the third person passive. That is, you do not use “I”, “you” or “we”, and generally write in a past tense. For example, "The humdinger valve was found to be faulty" not "We found the humdinger valve was broken". The language used should be clear, precise and as short as possible. The objective is to express complex ideas in simple language not simple ideas in complex language.

Report Assessment Process

The objective of the report assessment process is to get a satisfactory copy to the Company as soon as possible in order to maintain the momentum of the project and therefore maximise the chances of the recommendations being implemented.

Note it is your responsibility to get the report submitted on time to the Course Administrators. Passing it to anyone else, even members of staff, does not absolve you from that responsibility. Partially complete reports are deemed not to have met the deadline because they cannot be sent directly to the Company.

The Tutor will assess and correct the report, if necessary returning it to the project team, an assessment sheet will be sent to the project team and a copy of the corrected report will be sent to the company supervisor. His comments will be incorporated and the final version of the report will be published.

Assessment Criteria

The Tutor's assessment sheet provides Course Members with a written record of the Tutor's professional appraisal of the project work, the presentation feedback and the report. If a Course Member does not understand or agree with the appraisal he/she should arrange to discuss it with the Tutor. The assessment enables:

- The Course Members to monitor their own performance and develop self improvement plans.
- The Mentor to be aware of the Course Members performance standards.
- The keeping of a permanent record of the Course Members' performance to aid the writing of job references etc.

Project Handover

During the course of a project you will generate far more paperwork than can be reasonably included in the report. The larger the report the less attractive it is to start reading it. Therefore you need to consider how this information is to be handed over to the Company. The sort of information might include Supplier Brochures, brainstorming charts, web pages run off for background interest etc. These should be brought together in an index file and an appointment made to go through it with your project supervisor before you leave the Company. This will then enable someone to pick your work up and progress it.

A4.2 Exercise 1 - Student Briefing Note

Departmental Improvement Brief (Post Room)

Introduction

The post room of a wholesale and retail store dealing in engineers' small tools, is concerned with the packing and dispatch, by G.P.O. parcel post, of small orders to individual customers.

The sales department receives orders by post. These are processed, and an invoice, advice and assembly note and labels are typed. The advice and assembly notes are sent to the post room charge hand. The assembly note is packed with the parcel to allow the Customer's 'Goods In' to check the contents. The advice note is sent to the Customers 'Buying dept' to inform the Customer that the order is in the post.

Items for each parcel are brought from the warehouse by a serviceman. They are checked against an assembly note by the packer, packed, weighed, weight recorded on the parcel and on an advice note, and put for dispatch by a packer. This exercise is concerned with the packing operator's job.

Existing Method

An assembly and advice note is sent by internal post to the post room charge hand. The assembly note contains a list of the items required for one parcel. The serviceman gets the assembly note, collects the items required and takes them by trolley to the packing room. He deposits goods and assembly note on an assembly bench. Six assembly notes are dealt with at each trip which takes an average of 9 minutes.

The packer goes to the assembly bench. He checks the goods against the assembly note to make sure all items are correct. He takes the assembly note to the charge hand's desk and collects the advice note. He goes hack to the assembly bench and picks up the goods for the parcel and carries them all to his bench. He leaves the goods on the packing bench and walks over to the roll of corrugated paper, where he cuts off the length he requires to wrap the parcel. He goes hack to his packing bench and places the paper on the bench. He goes to a carton rack, selects the appropriate sized carton, goes back to his bench and makes up the carton. He then wraps the goods and the assembly note in the corrugated paper and packs them into the carton. He wraps the carton in brown paper, sticks a label on the parcel and ties it up with string. The labels are sent down with the advice note and the paper and string are kept on the packer's bench. He next takes the parcel to the weighing machine, weighs the parcel and returns with it to his bench. He records the weight on the advice note and parcel, takes the parcel to the rack for dispatch and the advice note to the charge hand's desk. He then goes to the assembly bench for a further parcel.

The internal post is as follows:-

Time of delivery	% of total notes delivered
7 a.m. (ex 4.30 p.m. post previous day)	11%
10 a.m. (ex 8.a.m. post)	81%
2 p.m. (ex 12 noon post)	8%

Parcels Data Registered and unregistered parcels are handled.

A registered parcel would require sealing in addition to the activities specified in the attached Flow Process Chart. Further information is as follows:-

	Av. Cycle Time to Pack	No. Av. per day
Unregistered Parcel	5 ½ mins	135
Registered Parcels	7 mins	45

All parcels are collected at 4.30 p.m. by G.P.O. on day advice note is received. It is Company policy that all parcels are dispatched within 24 hours of receiving the order.

Types of Goods Packed:

Hammers, Mallets, Chisels, Planes, Pliers, Rules, Spanners, Twist Drills, Screwdrivers, Tap & Die Sets, etc.

Staffing and Hours of Work

- 1 Charge hand - part time in this Department but has no other duties.
- 2 Packers - full time.
- 1 Packer - afternoons only (from 2.00 p.m.)
- 1 Service Operator - full time.

(The part time Packer is brought from another department so that all parcels are ready for dispatch by 4.30 p.m.)

Hours of Work:	Monday to Thursday (incl.)	07.00 - 17.00
	Friday	07.00 - 16.00 = 44 hours per week
	Tea Breaks	09.30 - 09.45 and 15.00 - 15.15.
	Lunch	12.00 - 13.00.

Payment

Rate of pay (excluding charge hand) is £5 per hour. No bonus scheme is in operation.

Furniture, Equipment and Layout

The furniture and equipment are placed according to the layout sketch. In addition one set of three tiered partitioned drawers is placed on each packing bench to hold labels.

Group Task

The Managing Director recently walked around the Post Room and pointed out that the work seemed inefficient. The area appeared over-staffed with staff having to walk long distances to pick up various items. You are the manager with the responsibility for the Post Room, amongst other areas, and have been asked to look into the matter. Your brief is to investigate:

1. The layout - is it inefficient?
2. Manning levels.
3. Are the company objectives being met?

Limits of Investigation

Management have stipulated that:-

a) No structural alterations to the room are permissible. Modifications, additions or disposal of the equipment in the room is permissible provided that a reasonable balance is maintained between costs and savings anticipated.

b) The charge hand must continue to be employed in his present rank and cannot be used for packing or service work.

c) No expansion of this work is envisaged.

d) The hours of the full time employees cannot be altered.

Any further information required will be given by the lecturer.

A4.3 Exercise 1 (Post Room) - Model Answer & Key Issues

The post room exercise is the first exercise in induction. It is very suitable for mixed abilities because it offers learning points in areas of different levels of difficulty. i.e.

Team work, planning a project and presentation skills

String Diagram and Layout Improvement

Manning Calculations

Averages and variation in demand

The average team gets as far as the manning calculations.

The learning points are drawn out by the tutor's facilitation during the exercise and the questions and answer during and after the presentation - 'learning by doing'. The brief asks the following questions:

Is the Layout efficient?

Are the Company Objectives being Met?

What Manning Levels are required to meet the objectives?

There is no model answer because the learning comes from doing the exercise and it mirrors reality where there are no right answers! A powerpoint presentation is available with a typical worked through answer and should be read in conjunction with this document. However, there is a difference between working through a methodical approach and inventive steps. The industrial problem solving lecture emphasises data based analysis, however, in industry breakthrough gains often come from inventive steps and these must not be discouraged but must be probed for reality

The Layout - is it inefficient? Typical Answer

The inference from the instructions is that you carry out a string diagram exercise. Since the second question is about manpower the string diagram should track man movements. The chargehand doesn't move, preliminary calculation shows the serviceman is only occupied 50% of the time therefore is not likely to be a constraint, therefore the diagram concentrates on the two full time packers.

This shows a total movement per parcel of 66.14m from the top bench and 50.29m from the lower packing bench. The main problems are the long diagonal movement to the carton rack and the despatch rack, and the movements to and from the chargehand table.

A revised layout can be drawn up, deleting the assembly table with the serviceman putting the parcels on the back of the packing desk. (Packing desks are 1.52m wide). Put the benches side by side to allow more flexible operation for the third packer, invest in an extra paper reel and put the reels & carton rack within reach of the packers. Place the weighing machine and chargehand desk next to the despatch rack, make the packers weigh, fill in advice and return to chargehand without returning to the bench. (the chargehand desk can be shortened to maintain gangway width.

This gives a travel distance per parcel of 17.37m for one packer and 17.98m for the other packer, the reduction in travel can be turned into a cycle time saving of 36 sec assuming a walk speed of 2.5 mph.

Issues

What to Plot - String diagrams can be used to track the movement of information, material or people, which you do depends on the statement of the problem and anticipated answers. If you are trying to improve throughput or reduce inventory you plot material, if you are trying to improve manning you plot people movement. As stated above in this exercise the preliminary evidence points towards plotting movement from the two packing benches.

Where to put the Pins - the scale of the layout is quite large and an allowance has to be made for the position of the operators standing at the workplace and the items within his reach.

Use of Direct Routes - A common error is to run the strings over the assembly bench or other furniture. The strings have to pass around obstacles assuming a virtual gangway of 0.76m.

Where does the third man work - On the original layout there are two work stations for the purposes of calculation you can average the results and apply them to the third man. (For the inventive there are other assumptions i.e. the further packer could do the registered parcels and therefore reduce the percentage of travelling)

Do you use all the furniture - there is a tendency to want to use all the furniture; the packing benches at 2.74m x 1.52m and the chargehand's desk at 2.44m x 0.91m are very large. The graduates don't relate this to the working area of a standing man. You can throw away or shorten the assembly bench and cut down or use part of the chargehand's desk.

Can you have new furniture - Payback seems fairly certain on extra paper reels or carton rack, the weighing machine is more dubious. High tech solutions such as direct printers for invoices etc., would have a payback if the chargehand wasn't so under-utilised.

Gangways - Layouts often lack gangways and the health and safety aspects of gangways and fire hazards can be discussed, i.e. are there any, inadvisability of working with your back to a passage particularly at junctions etc.

Working Environment - Do you put people working face to face - more sociable but less productive, back to back - reinforces the monotony of the job or side by side.

Manning Levels - Typical Answer

The first gross answer shows that the packers are utilised in the original layout 92% of the time, while the serviceman is utilised 53% of the time. Therefore it seems appropriate to consolidate the service and packing tasks.

The re-layout reduces the required hours by 9.1 per week, leaving an excess of hours available at current manning over average load of 35.7hrs/ week . This Department manager would have to decide whether to try and reduce by the part time packer (12.8hrs/wk) or one full time packer (41.5hrs/wk).

To take out one packer there is a shortfall of 41.5 - 35.7 hrs/wk = 5.8, this can be partially recovered by the chargehand delivering and collecting notes - 1.8hrs travel time and taking the parcels to despatch in batches of six - 1.4hrs. Leaving a shortfall of 2.6hrs/week.

In practice the greater time would be gained by the chargehand handling the paperwork than just the travel time, it must have beneficial effect on the cycle time but there is insufficient data to quantify the gain; also the 2.5mph average speed is conservative. In real life one would take out a whole man and assume if necessary a 3% performance improvement could be achieved.

Issues

Units of Calculation - There are numerous ways of basing the calculation, minutes per parcel, parcel per packer etc., most of these give difficulties with the shortened Friday working day. The easiest calculation basis is to work in hours/week required and available.

Reduction in manpower - some teams still identify decimal men as the saving, without realising to make a saving either the part packer or a full time packer has to be made redundant or redeployed. One proposal is usually to eliminate the part time packer and make the full time packer part time, this would still be viewed as redundancy by an Industrial tribunal. The tribunal view of redundancy can be explained.

Reductions in Time - The hard data is available for travelling time only. The teams ask how fast a man can walk and can be advised to measure it. When jobs such as handling advice notes are analysed working assumptions have to be made.

Use of Averages - The straight forward calculation covers the average daily rate, for the teams who get no further and have reduced manpower to the minimum a they need to consider what the likely variation in demand could be and what strategies there are for dealing with it.

There is a deliberate inconsistency in the handout to emphasise the importance of not taking all data at face value.

Are the Company Objectives being met? Typical Answer

The only explicit Company policy is that all parcels are despatched on the day the order is received in the post room. Obviously the Company would also have objectives of efficiency and cost effectiveness. A simple graph can be drawn to show assembly notes available for picking and kits available for packing i.e. serviceman and packer workload. This shows that only 69% of the days order are packed on the same day. Furthermore the calculations in the previous section are thrown into question because if there were no backlog there would be no work for the packers between 8.00 and 10.00 am.

Combining the service and packing operations and taking into account one less packer and the efficiency savings listed above can also be plotted this results in an improvement with 84% of parcels packed on the correct day.

To reach the required service level two improvements can be made - the chargehand can fetch the first two batches of orders before the 10.00 post, this could be done in two trips 8.15 a.m. and 9.00 a.m. In addition the part timer hours should be renegotiated instead of 2.00 to 5.00 pm he should work 10.00 to 2.00, this would give additional flexibility because he could be kept on longer to ensure that variations in demand were met.

This has the advantage of meeting the policy but gives no work in the last half hour of the day.

Issues

Levels of Data & Assumptions - This stage of the exercise requires more assumptions and creative solutions with little evidence available, it provides a platform for the debate of how much evidence you would gather in real life before you made a decision.

Wisdom of Policy - The two constraints of not being able to alter the hours and having to catch the last post at 4.30 creates an unusable half hour at the end of the day. There is a debate of whether to change one of the policies or accept the loss of manpower performance.

Implementation Plan - In the various options the teams come up with the ‘doability’ should be challenged, which approaches can be tried before you are committed and which require an ‘act of faith’ from which there is no return.

Project Planning and Presentation - Typical Approach

The project is planned for 8 hours of which the last hour is a set of presentations, a reasonable plan is:

First hour: Read notes, discuss problem, draw up rough cut process and manpower utilisation calcs. Draw up plan and agree tasks.

Second & Third hours: One partner carry out string diagram for current situation, second partner do manpower calcs for current manning.

Four & Fifth hours: Brainstorm ideas for alternative layouts, compare alternatives and plot revised string diagram.

Sixth Hour: Work out improvements from revised layout and brainstorm alternative manning levels, compare alternatives and pick optimum result.

Seventh Hour: Prepare Presentation.

Issues/Learning Points

Since this is the first exercise most teams don’t think to plan the exercise, they start by doing a string diagram.

There is a tendency for partners to work on the same task rather than divide the problem between them, this only happens in the later part of the exercise when they run out of time.

Very few groups carry out a quantitative comparison of alternatives, generally they will go with the first idea that looks feasible.

Although the exercise naturally works in a sequence decisions taken at the later stages can require a reappraisal of earlier analysis, for example it does not seem necessary to measure the work of the serviceman but if you later decide to integrate his task that data becomes required. Some of these problems can be avoided by the initial rough-cut analysis before starting the project.

The success of the presentation is based heavily on an ability to portray the data in a graphical, easily understandable form. Spreadsheets are easy to get lost in and impossible to explain in a five minute presentation.

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